AD-A076 138 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 19/6
COMBAT DAMAGE ASSESSMENT TEAM, A-10/GAU-8 LOW ANGLE FIRINGS VER--ETC(U
AUG 79 R H STOLFI , J E CLEMENS MIPR-F47615-78-5209
UNCLASSIFIED NPS56-79-006 NL

1 OF 1
AD A076 138

END
DATE FILMED
11-79
DDC

NPS56-79-006

(2) LEVEL II

NAVAL POSTGRADUATE SCHOOL

Monterey, California

COMBAT DAMAGE ASSESSMENT TEAM
A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS
SIMULATED SOVIET TANK COMPANY
(15 June 1978)

R.H.S. Stolfi

J.E. Clemens

R.R. McEachin

August 1979

Prepared for: A-10 System Program Office
Wright Patterson Air Force Base
Ohio 45433

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral Tyler F. Dedman
Superintendent

Jack R. Borsting
Provost

The work reported herein was supported by the A-10 System Program Office, Wright Patterson Air Force Base, Ohio. The reproduction of all or part of this report is authorized.

Russel H.S. Stolfi
Associate Professor of History

Reviewed by:

Edward J. Laurance
Assoc. Chairman
Department of National
Security Affairs

Released by:

W.M. Tolles
Dean of Research

UNCLASSIFIED

(9) Special repte,

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (14) NPS56-79-006 ✓	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) (6) Combat Damage Assessment Team, A-10/GAU-8 Low Angle Firings Versus Simulated Soviet Tank Company (15 June 1978)	5. TYPE OF REPORT & PERIOD COVERED Special Report for Array Firings of 15 June 1978
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) R.H.S. Stolfi, J.E. Clemens, R.R. McEachin	8. CONTRACT OR GRANT NUMBER(s) None (12) 89
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940 (15) MIPR - MIPR -	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS F 47615-78-5209, and FY-7621-78-90220
11. CONTROLLING OFFICE NAME AND ADDRESS A-10 System Program Office Wright Patterson Air Force Base Ohio 45433 (1)	12. REPORT DATE August 1979
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*	15. SECURITY CLASS. *(of this report)* Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

(the first in a two volume set,

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

1. automatic cannon ammunition
2. GAU-8 cannon
3. A-10 aircraft
4. main battle tank (MBT)
5. empirical tests
6. combat stowed targets
7. gun ammunition lethality
8. MBT vulnerability and survivability

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report, describes firings of the A-10/GAU-8 weapon system on 15 June 1978, against a Soviet tank company simulated by ten combat loaded M-47 tanks. The pilots making the firing passes attacked at low altitude and corresponding low dive angles simulating movement through a hostile air defense system. Ammunition used in the attacks comprised 30mm armor piercing incendiary rounds, which proved to be effective damage agents against substantial areas of the U.S. M-47 tanks used as targets. The

(over) JCB

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

251 450

pilots in 23 firing passes achieved 347 impacts on the ten target tanks. The impacts included 50 perforations of the armored envelopes and resulted in damage comprising six tanks catastrophically killed, three tanks incapable of fire and movement, and one tank with degraded mobility.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Illustrations

COMBAT DAMAGE ASSESSMENT TEAM

A-10/GAU-8 LOW ANGLE FIRINGS

versus

SIMULATED SOVIET TANK COMPANY

(15 June 1978)

EXECUTIVE SUMMARY

DR. R.H.S. STOLFI, Naval Postgraduate School

MR. J.E. CLEMENS, Battelle Columbus

MR. R.R. McEACHIN, Battelle Columbus

EXECUTIVE SUMMARY

Under the technical direction of the Combat Damage Assessment Committee (CDAC), the Combat Damage Assessment Team (CDAT) conducted firings of the A-10/GAU-8 weapon system against an array of 10 tanks simulating a Soviet tank company deployed for an attack. The CDAT used M-47 tanks stowed with main gun ammunition, diesel fuel, lubricating oil, and crew mannikins to simulate the Soviet tanks. The pilots of the two A-10 aircraft used in the firings conducted their firings at low altitudes and low dive angles which simulated attack below the altitude of effective engagement for opposing air defense networks employing acquisition and fire control radar. The purpose of the test was to evaluate the effects of the 30mm API antitank ammunition of the GAU-8 gun under challenging conditions of engagement for the A-10/GAU-8 system against realistically simulated Soviet tank formations.

The Combat Damage Assessment Committee assessed the results of the low angle cannon firings of the two A-10 aircraft against the simulated Soviet tank company as follows:

1. Attack Parameters: The pilots of the A-10 aircraft attacked the simulated Soviet tank company for 10 minutes 30 seconds at low altitude and dive angles. The pilots made a total of 23 passes each at a primary tank target. The passes resulted in projectile impacts on 23 primary, ten secondary, and 5 incidental target tanks, i.e., the pilots impacted every primary tar-

get and in addition inflicted damage 18 times each on secondary and incidental tank targets near the primary. The attack open fire dive angles averaged 7.1° during 23 passes against the targets. Open fire slant ranges averaged 2759 feet and cease fire slant ranges 2078 feet. The pilots fired 1969 rounds in 23 bursts averaging 86 rounds and 1.3 seconds each.

2. Weapon Effects: The A-10/GAU-8 weapon system achieved 347 impacts on the ten tank targets. The ratio of impacts to total rounds fired was a substantial 0.18. The weapons system achieved 50 perforations of the armored envelopes of the tanks with a ratio of perforations to impacts of 0.14. Many projectiles, which did not perforate armor, severely damaged exterior track and suspension components of the tanks as well as command and control optical devices and gun tubes.

3. Damage Assessment: The attacking A-10/GAU-8 weapon systems inflicted six catastrophic kills on tanks in the company array. Three additional tanks in the array did not explode or burn but were severely damaged within the time frame of the aerial attack and rendered incapable of both fire and movement. One final tank in the array suffered only moderate damage; it remained capable of firing but was reduced in its ability to maneuver. As a formation, the simulated Soviet tank company was for any practical purpose destroyed.

4. Test Conditions: The target tanks were sited in open, flat desert terrain with no cover and little concealment. Aerial weather conditions were ones of unlimited ceiling and visibility.

Shortly after the initial firing passes black smoke from burning and exploding tanks and clouds of white dust from projectile impacts were evident. Such conditions effectively simulated the actual obscuration which would have been presented to the pilots in combat and reduced their effectiveness in several firing passes as evidenced by in-flight voice recordings of the mission.

5. Summary and Conclusions: Under contrasting firing conditions of ideal weather and open, flat terrain but challenging low altitude attack parameters and battlefield smoke and dust obscuration, the A-10/GAU-8 weapon system knocked out nine of ten tanks in the simulated Soviet tank company. The term, knocked out, comprises the following conditions: six tanks suffered internal explosions and fires and three additional tanks were immobilized and simultaneously rendered incapable of firing their main armament. The observed and documented results support the conclusion that:

a. The A-10/GAU-8 weapon system employing 30mm API projectiles has the accuracy and lethality to destroy M-47 and similarly protected tanks, e.g., Soviet T-55 and T-62 tanks, under realistic firing conditions.

b. GAU-8 30mm API projectiles fired in realistic low level passes by A-10 aircraft can perforate the sides and rear of main battle tanks and cause catastrophic damage through explosion of tank ammunition and ignition of fuel and oil.

c. GAU-8 30mm API projectiles which do not perforate the armor of main battle tanks have the capability to immobilize them through damage to exterior track, suspension, and drive components.

d. From the viewpoint of GAU-8 30mm API ammunition effects and resulting damage to combat stowed main battle tanks, the tactic of low level attack was shown in this firing test to be a successful one.

6. The overall results of the test are summarized in the accompanying Table I.

TABLE I.

TWO A-10 AIRCRAFT IN LOW ANGLE GUN ATTACK VS SIMULATED SOVIET TANK COMPANY

A-10† PASS NO.	TANK TARGET NO.	A-10 APPROACH†† SPEED (FPS)	ALT (FT)	A-10 ATTACK†† OPEN FIRE RANGE (FT)	DIVE ANGLE (°)	GUN EFFECTS ROUNDS* (EACH)	IMPACTS (EACH)	PERFS (EACH)	DAMAGE M	F	K	TANK IMMOB	TANK ASPECT
P1-3	6	540	290	2682	6.9	96							
P1-6	6	521	355	2000**	10.6	89	32	3	-	-	K	100	RT SIDE
P2-11	6	509	-	4523	6.5	115							
P2-2	5	554	-	3329	4.4	64							
P1-8	5	551	370	2710	9.9	69	76	9			K	100	RT SIDE
P1-1	16	578	180	2186	5.3	70							
P2-8	16	546	-	3448	8.3	80	30	8	-	-	K	100	RT SIDE
P2-10	16	527	-	3683	10.4	103							
P2-6	12	527	-	2619	6.5	64							
P1-7	12	557	200	2024	5.8	52	32	7	100%	100%	-	100	RT SIDE
P2-4	11	527	-	3178	5.6	165							
P2-7	11	518	-	2099	5.6	96	34	7	-	-	K	100	RT SIDE
P2-5	2	499	-	2870	10.9	103							
P1-5	2	538	165	2373	5.4	75							
P1-9	2	536	395	2434	10.1	83	59	4	100%	95%	-	100	RT SIDE
P1-10	2	548	290	2253	7.6	61							
P1-11	2	547	315	2152	10.0	58							
P2-3	7	509	-	4055	5.8	117	12	1	35%	0	-	-	RT SIDE
P1-2	14	546	-	2296	4.4	68	14	6	-	-	K	100	RT SIDE
P2-1	15	523	-	2264	4.2	43	25	3	-	-	K	100	RT SIDE
P1-4	4	530	250	2795	5.4	129							
P2-9	4	527	-	3087	7.4	95	33	2	70%	100%	-	-	RT SIDE
P1-12	4	543	340	2401	7.9	74							
23	TOTALS OR AVERAGES	535	286	2759	7.1	86	35	5	6 TANKS K-KILLED 8 TANKS IMMOBILIZED				

NOTES: †A-10 FIRED AT TARGET NOTED; RDS MAY HAVE IMPACTED ADDITIONAL TARGETS. ††OPEN FIRE SPEED, ALTITUDE, RANGE.

*RDS FIRED AT TARGET NOTED; RDS MAY HAVE IMPACTED ADDITIONAL TARGETS. **ESTIMATED.

COMBAT DAMAGE ASSESSMENT TEAM

A-10/GAU-8 LOW ANGLE FIRINGS

versus

SIMULATED SOVIET TANK COMPANY

(15 June 1978)

REPORT

DR. R.H.S. STOLFI, Naval Postgraduate School

DR. J. E. CLEMENS, Battelle Columbus

MR. R.R. McEACHIN, Battelle Columbus

REPORT

I. Background

Since February 1978, the Armament Directorate, A-10 System Program Office, Wright Patterson Air Force Base, Ohio, has conducted firing tests using the A-10/GAU-8 system in low level, air-to-ground engagements of armored targets. The tests have been conducted within the framework of the GAU-8 30mm ammunition Lot Acceptance Verification Program (LAVP)-Airborne. The LAVP has the following objectives which apply to the present tests:

A. To evaluate the performance of existing production lots of GAU-8 ammunition when fired from the air under operational conditions.
B. To evaluate the lethality of GAU-8 ammunition against armored targets when fired at low level from A-10 aircraft using operational tactics.

To conduct the LAVP program, the Armament Directorate has coooperated with Headquarters, Tactical Air Command, Langley AFB, Virginia and in turn with the Tactical Fighter Weapons Center, Nellis AFB, Nevada. Within the framework of that cooperation, the Armament Directorate has set up a Combat Damage Assessment Team (CDAT) to plan and execute the firing tests and evaluate the results. The CDAT functions under the direction of a Combat Damage Assessment Committee (CDAC) which has prepared this report of the firing test of 15 June 79.

II. Test Philosophy

To generate realistic data, the CDAC determined to use a highly empirical technique of destructive testing of actual target tanks. Tests have involved firings at individual tanks in November 1977 and February - March 1978, and more recently, arrays of vehicles in tactical formations. The experimental setup for the firings of 15 June 78 involved the second use of a multitarget, tactically arrayed tank formation for attack by the A-10/GAU-8 system. The CDAC elected to simulate a Soviet tank company as organized within a tank division as the target array for two attacking A-10 aircraft. As few constraints as possible were placed on the attacking pilots in an attempt to develop as much realism as possible. Figure 1 shows the test factors which would have been ideal in the test of 15 June 78 and the practicable setup which was achieved.

III. The Simulated Ground Combat Situation

The firing test of 15 June 78 simulated the attack by two A-10 aircraft on a Soviet tank company. The CDAC hypothesized the Soviet tank company to be the lead march security detachment for the battalion, which in turn, is the advance guard of a larger mobile formation. The lead detachment is operating approximately five kilometers in front of the Soviet battalion column. The mission of the advance company is to ensure the uninterrupted advance of the battalion and provide security against attack. Upon meeting heavy resistance, the company

FIGURE 1.

Empirical Test Philosophy

Comparison of Ideal & Practicable Test Situations

Ideal Test Parameters	Practicable Test Parameters
1. Air Attack Realism	1. Air Attack Realism
a. Actual A-10/GAU-8	a. Actual A-10/GAU-8
b. 30mm APIT	b. 30mm APIT
c. European Weather & Terrain	c. Nevada desert terrain and Weather
d. Optimum open fire ranges (2000 feet)	d. Long open fire ranges (4000-3000 ft safety constraints)
e. Low altitude attack ($\prec 5°$ Dive Angle)	e. Low altitude attack ($\prec 5°$ Dive Angle)
2. Air Defense Realism	2. Air Defense Realism
a. Automatic cannon firing at A/C	a. Low altitude, low angle, minimum exposure attacks vs assumed AD system
b. Missile systems firing at A/C	b. Ditto
c. Small arms firing at A/C	c. Ditto
d. AD suppression by A/C	d. No suppression simulation in test
3. Threat Targets and Doctrine	3. Threat Targets and Doctrine
a. T62/T64/T72 high fidelity-targets	a. Simulated Soviet Tanks
b. Stowed combat loads (in T-62/T-64/T72)	b. Stowed combat loads (in US M-47)
c. Realistic crew station postures	c. Wooden crew mannikins
d. Dynamic combat formation	d. Static combat formation
e. Maneuvering evasive targets	e. Stationary targets

deploys into an appropriate combat formation to reduce the resistance or form a base of fire for offensive action by the remainder of the battalion.

A Soviet tank company, which is operating as simulated in the firing test, would probably have other units attached to it for its support. Attached units might include any one or all of the following elements: (1) motorized rifle platoon, (2) engineer detachment, (3) chemical defense element. The lead attachment simulated in the firing test consisted of tanks alone. The pure tank formation was arranged with two platoons up and one back simulating an assault posture. The tanks used in the firing test were US M-47 tanks. The tanks were not maneuvered during the firing test and the formation was essentially a "snapshot" of the company at a single point in time (See Figure 2).

IV. The Target Tanks

The US M-47 tank was the most effective target available in sufficient numbers to simulate Soviet T-55 and T-62 tanks. The US tank is similar in armor protection to the Soviet tanks, and with the appropriate purging of its gasoline fuel system a similar target from the viewpoint of stowed fuel. The most significant difference in survivability among the vehicles is the superior protection of the M-47 tank at the rear of the turret attributable to the extreme overhang and attached stowage box.* The Soviet T-64 tanks are ill-understood from the viewpoints of

- - - - -

*See Sketch 1.

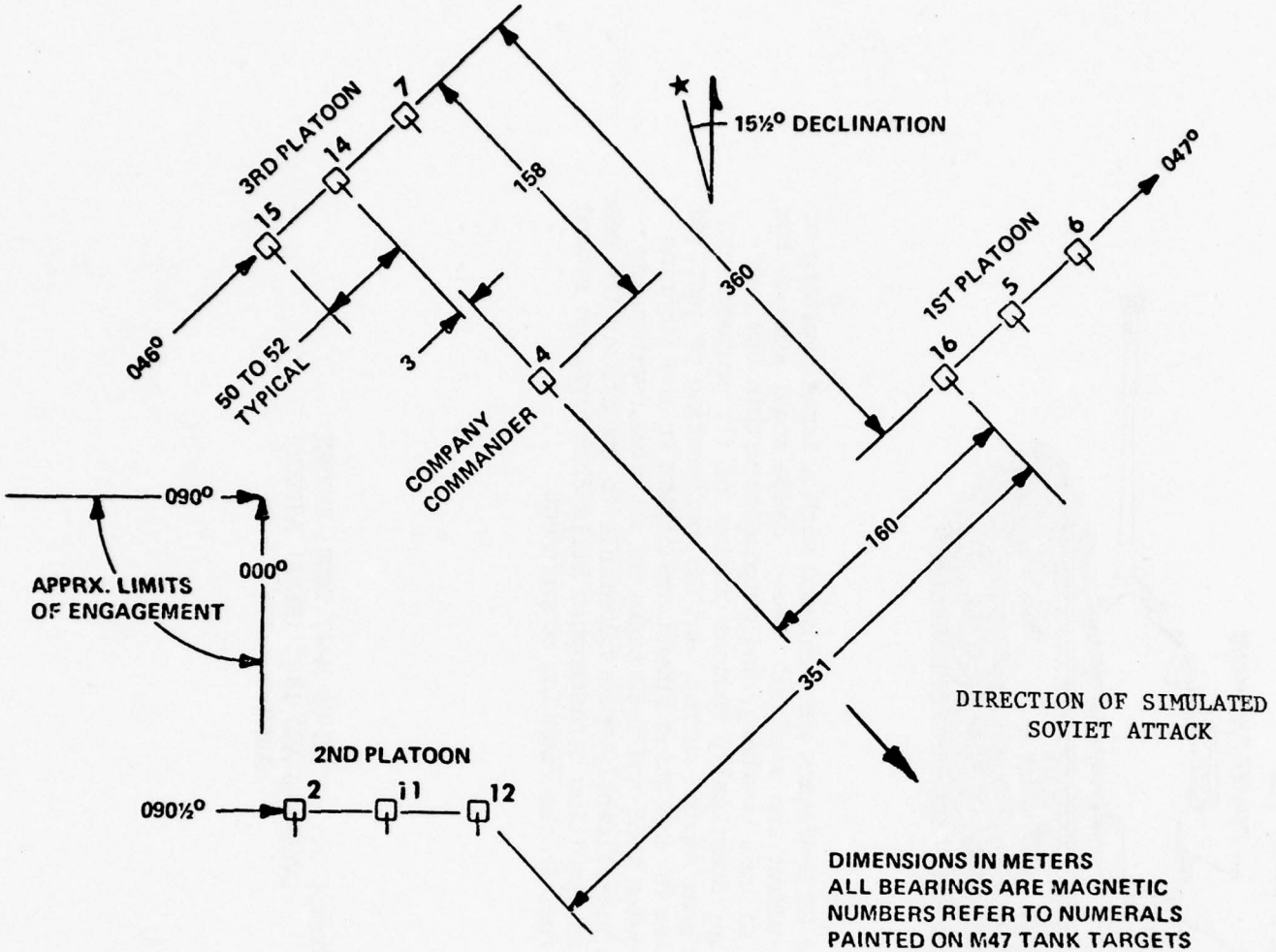
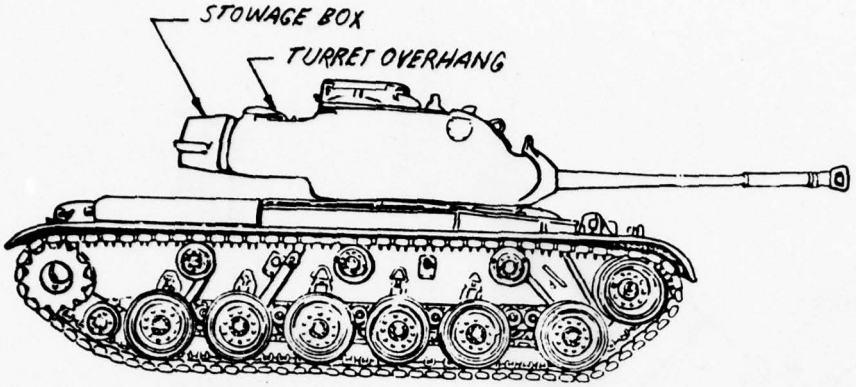


Figure 2. -- THE TANK TARGET ARRAY



DISCUSSION: The US M-47 tank was designed with a large overhang at the rear of the turret and attached heavy gauge steel stowage box. The combination of box, overhang, and components within the overhang of the turret drastically reduces chances of (1) projectiles perforating the rear of the turret, and (2) perforating projectiles causing casualties or impacting stowed ammunition in the fighting compartment. Soviet T-55 and T-62 tanks do not have overhanging turrets and are significantly more vulnerable to impacts at the rear of the turret and resulting catastrophic kills from impacted stowed ammunition and fuel in the fighting compartment.

Sketch 1. -- THE US M-47 TANK: TURRET OVERHANG AND 180° (REAR) ASPECT SURVIVABILITY

armor protection and the arrangement of internal components. The decision was made, accordingly, to simulate the better known, earlier model Soviet tanks with the readily available M-47 vehicles.

The M-47 tanks used for targets were in excellent condition from the viewpoint of damage assessment. The exterior components were complete and the tanks have proven to be effective targets for the collection of exterior mobility damage. Interior components were less complete in the target tanks. All of the most essential items were present, e.g., main gun, engine, transmission, fuel tanks, ammunition racks, etc., but other items such as oil coolers, range finders, vision devices, and radios, were not present in all tanks.

The most sensitive internal items from the viewpoint of catastrophic kills and high percentage M and F kills are the following, which were placed in the test tanks as noted:

Generic Sensitive Item	Test Item
1. Ammunition	US Cartridge, 90mm TP-T
2. Fuel	Number 2 Diesel
3. Oil	Oil in Engine, Transmission and Drive Components
4. Personnel	Articulated Plywood Mannikins

The tanks were static during the test and their engines were not running, with the result that the fuel and oil were much cooler and more inert than would have been the case with a static vehicle with its engine running. The kill ratio achieved in the firing test of 15 June 78, therefore, is probably conservative from the viewpoint of fires resulting from ignited fuel and oil.

V. The Test and Results

The test itself consisted of bringing together the ammunition, gun, aircraft, pilots, and combat arrayed and loaded tanks into a several minutes simulation of combat. In essence, the decisive elements which had been fed into the test immediately prior to the firing were the following:

1. Honeywell 30mm API ammunition.
2. General Electric GAU-8 Gatling gun.
3. Fairchild Republic A-10 attack aircraft.
4. USAF Fighter Pilots, 422d FWS, Nellis AFB.
5. US M-47 main battle tanks.

The combat simulation itself comprised the aerial fire and maneuver of the attacking A-10 aircraft. A realistic way of presenting the combat simulation is to outline the sequence of pertinent events in each firing pass. The sequence of events and pertinent data which the CDAT attempted to collect in order to reconstruct the simulated combat firing of 15 June 79 were the following:

Sequence	Event	Data
1.	Aircraft Approach	Speed, Altitude
2.	Aircraft Attack	Open Fire Range, Dive Angle
3.	Aircraft Attack	Burst Time, Rds (R) Fired
4.	Aircraft Attack	Cease Fire Range, Dive Angle
5.	Gun Effects (Accuracy)	Impacts (I) on Tanks, (I/R)
6.	Gun Effects (Lethality)	Perfs (P) Thru Armor, (P/I)
7.	Tank Damage	Catastrophic Kills
8.	Tank Damage	Mobility (M), Firepower (F) Kills

The data noted immediately above were collected through the combined efforts of the CDAT and range personnel at Nellis AFB working together and using TSPI equipment, motion picture and

still cameras, the industrial efforts required to repair, refurbish, and field the tank targets, and various systematic research techniques used to describe weapon effects and combat damage. The most basic materiel used in the test - the projectile, gun, aircraft and targets - are illustrated in Figures 3 through 6. The targets were arrayed in the tactical formation of a Soviet tank company as shown in Figure 2.

The pilots making the attack worked in a two-ship, mutually supporting element and employed operational tactics throughout the test passes. The pilots approached the target area at low altitude and simulated target acquisition with the help of a forward air controller. The pilots then pressed in their attacks on the acquired targets at low altitudes and low dive angles simulating operations under the altitudes for effective acquisition and tracking by opposing air defense systems.

The A-10 maneuvering and firing during each pass at a primary target are presented in terms of basic data such as speed, dive angle, etc. in the following photographs and accompanying tables and figures. Weapon effects, various measures of effectiveness, e.g., kills per pass, other ratios, etc. and the resulting damage are noted in other paragraphs, tables, and photographs in the following section of the report.

Table II presents the test in terms of the A-10 speed during firing and is based on time, space, position information (TSPI) and the reading of heads up display (HUD) camera film. The table shows the A-10 aircraft attacking at speeds during

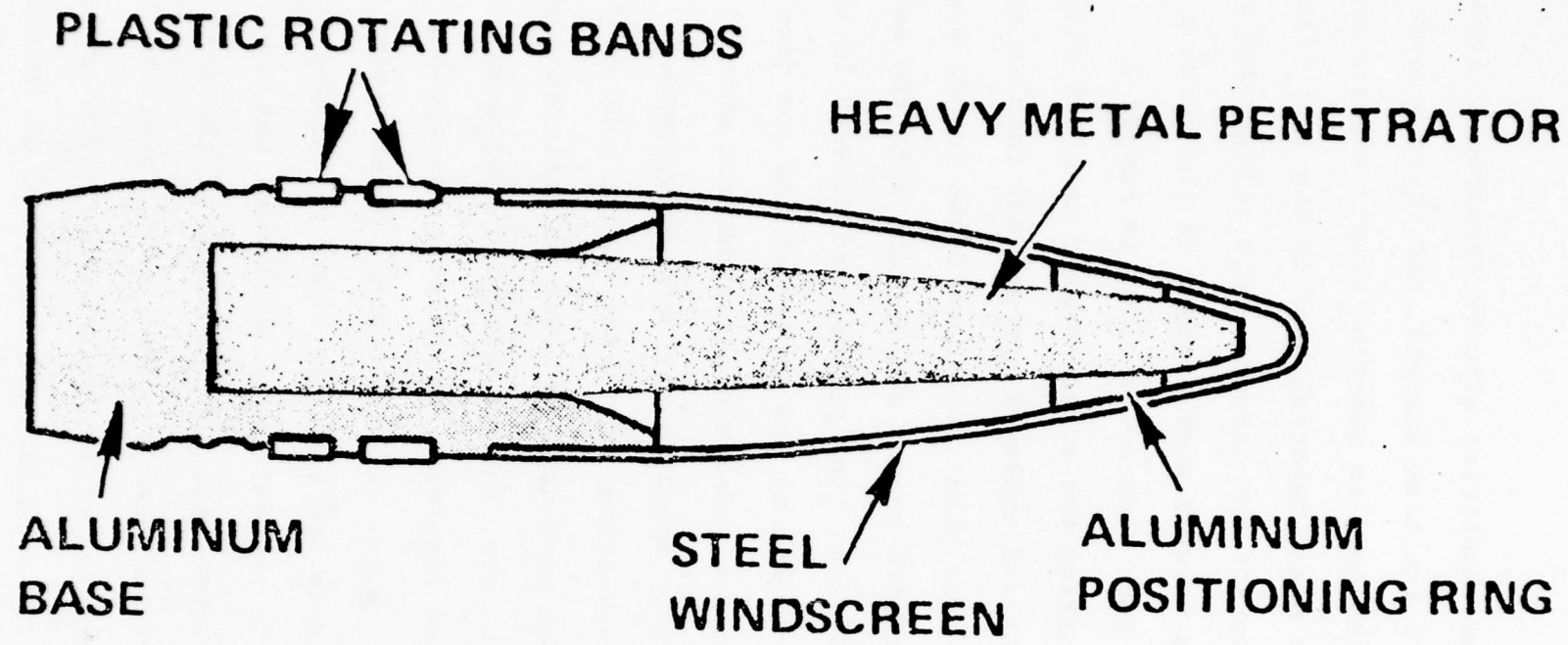


Figure 3. -- THE PROJECTILE: 30mm API for GAU-8 GUN

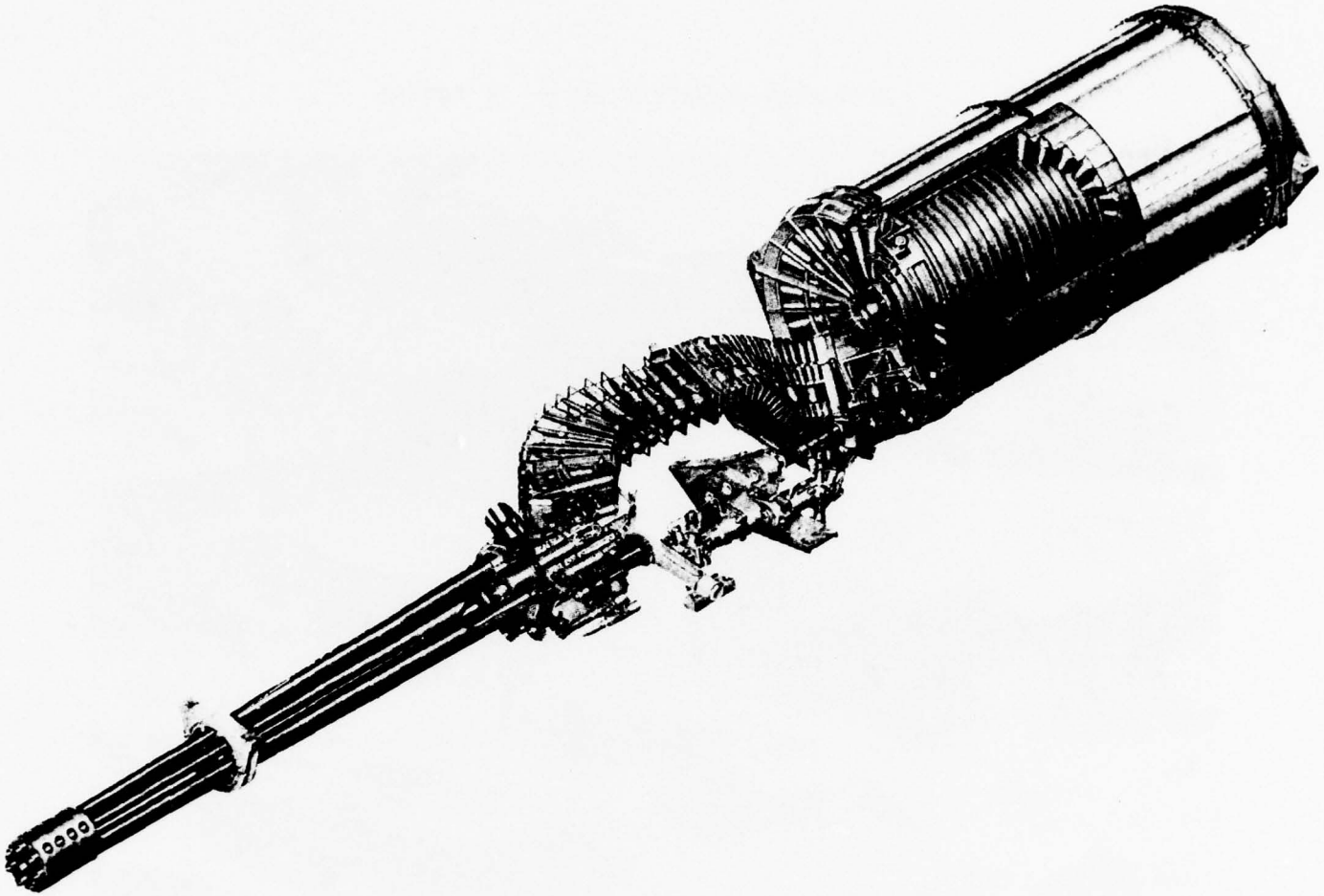


Figure 4. -- THE GUN: GAU-8 30mm GATLING

Figure 5. -- THE AIRCRAFT: USAF A-10

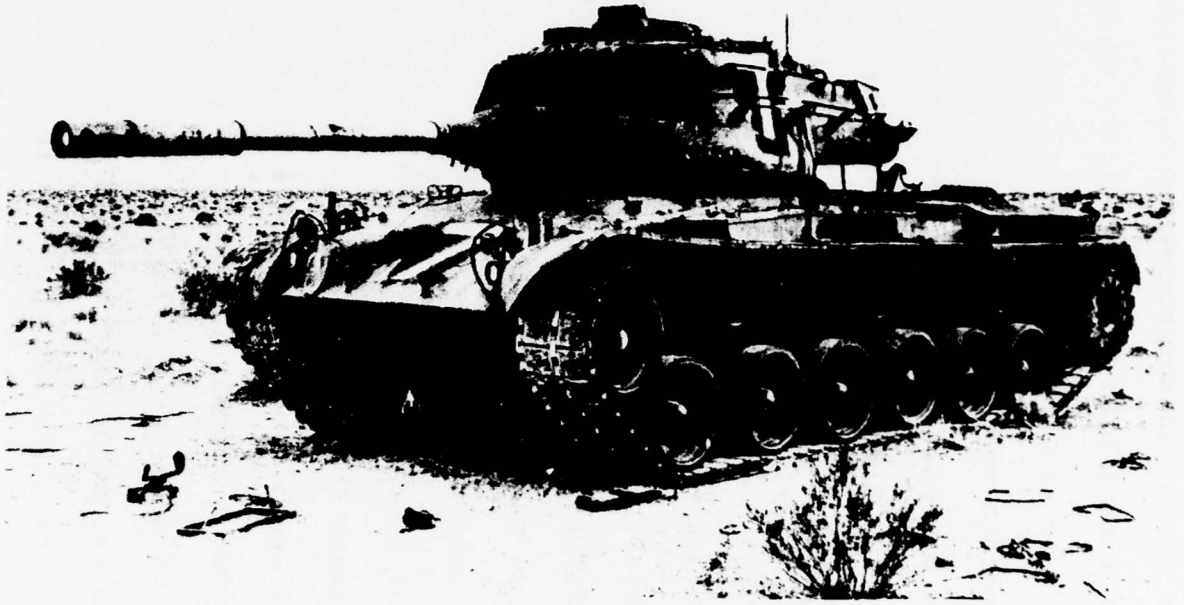


Figure 6. -- THE TARGET: M-47 COMBAT TANK

the firing passes varying between 578 ft/sec (342 knots) and 499 ft/sec (295 knots) and averaging overall 535 ft/sec (316 knots). The firing speeds largely in excess of 300 knots combined with the clean, unencumbered configuration of the aircraft resulted in exceptional maneuverability of the aircraft during the attacks on the tank company.

Table III presents the test in terms of the A-10 dive angles during the firing passes. The clearly configured aircraft were able to attack at low dive angles ranging between 4.4 and 10.8 degrees. The low dive angles resulted in an overwhelming predominance of impacts against the side surfaces of the hulls and turrets of the target tanks and relatively low vertical obliquities. In the test of 15 June 78, the M-47 tanks proved vulnerable to perforation through the armored side surfaces partly because of the dive angles and resulting low vertical obliquities.

The next illustration, Table IV, shows open fire slant ranges for pass at a primary target. The attacking pilots opened fire at medium ranges for the A-10/GAU-8 system averaging 2795 feet. The actual open fire ranges clustered near the statistical average, and, as medium ranges of engagement they resulted in effective ratios of accuracy and lethality for the system.

Figure 7 is extracted from an in-flight recording of the pilots' comments during the firing. The recording shows that the pilots were faced with realistic battlefield obscuration, specifically smoke from the fires and explosions within the tanks which they had catastrophically damaged.

Figures 8 through 10 are plots of the A-10 attack path in a vertical plane against targets located at 0-0 in the display. The figures define the path of attack immediately before, during, and after the firing and represent an instant summary of the more important aircraft attack parameters including altitude, firing range, and dive angle (note unequal scales in feet on x and y axes).

Table V shows the burst length and number of rounds fired during each pass. For aircraft P1, the average burst length was 1.17 seconds, which was realistically short from the viewpoint of non-maneuvering exposure to air defense fire. For the same aircraft, the average number of rounds fired was 77, which was a moderate amount, but one which promised effective numbers of impacts on targets and perforations through the armored envelope based on empirical ratios developed during testing in the LAVP. For aircraft P2, similar comments can be made.

Table VI shows the arrival mode of the projectiles which impacted the target tanks and the projectile effects in the cases where the projectiles impacted armor. The table shows that 90% of the projectiles directly impacted the target tanks while 10% arrived as ricochets off the ground. The direct impacts in turn were broken down into 53% which directly impacted the armor, and 47% which hit exterior components with varying but largely insignificant results against the armor.

Catastrophic damage to tanks largely comprises the effects of internal fires and explosions. Table VII shows the development of catastrophic damage in the tanks of the target array in terms of the observed progress of internal fires. Tanks 11, 14, and 15, for example, were observed to burn, i.e., suffer from major internal fires and/or explosions, within 5.6 minutes of the initial firing pass.

Table VIII summarizes the damage inflicted in the firing passes and shows six tanks with catastrophic damage, three tanks with either complete or extremely high degradation of both mobility and firepower, and one tank with moderate degradation of mobility.

Table IX summarizes the distribution of perforations on the armored surfaces of the target tanks. It shows the unusual fact that 48% of the perforations were thru the turret, which comprises approximately 33% of the presented area. Partial explanation for the phenomenon is the shielding effects of the suspension components on tank hulls.

Figure 12 ties together aircraft attack parameters, weapon effects, and target damage, in effect, summarizing the entire firing test. The table shows that the pilots/planes/cannons had the skill/performance/effects to immobilize the MBTs in 38% of the firing passes and catastrophically destroy them in 26% of the passes. One of the most pressing missions of the A-10 is to blunt attacking enemy armored spearheads by physically halting (or slowing) the attacking armor. Halting enemy armor gives US Army and allied ground forces the

opportunity (1) to concentrate against deeply penetrating spearheads, and (2) to destroy more easily the immobilized or slowed enemy armor. The capability of the A-10 to halt enemy armor, thus, is at a premium, and the figure shows a particularly significant capability for immobilizing the main battle tanks used in the forcing tests to simulate a Soviet tank company in the attack.

PASS	AIRCRAFT VELOCITY (feet per second) OPEN-FIRE	CEASE-FIRE	AVG	SOURCE	±2σ TOLERANCE (feet per second)
P1-1	578	578	578.0	TSPI	12
P2-1	573	564	568.5	HUD FILM	17
P1-2	546	536	541.0	HUD FILM	17
P2-2	554	546	550.0	HUD FILM	17
P1-3	540	539	539.5	TSPI	12
P2-3	509	509	509.0	HUD FILM	17
P1-4	530	510	520.0	TSPI	12
P2-4	527	518	522.5	HUD FILM	17
P1-5	538	533	535.5	TSPI	12
P2-5	499	509	504.0	HUD FILM	17
P1-6	521	518	519.5	TSPI	12
P2-6	527	527	527.0	HUD FILM	17
P1-7	557	556	556.5	TSPI	12
P2-7	518	518	518.0	HUD FILM	17
P1-8	551	552	551.5	TSPI	12
P2-8	546	546	546.0	HUD FILM	17
P1-9	536	531	533.5	TSPI	12
P2-9	527	536	531.5	HUD FILM	17
P1-10	548	546	547.0	TSPI	12
P2-10	527	518	522.5	HUD FILM	17
P1-11	547	550	548.5	TSPI	12
P2-11	509	509	509.0	HUD FILM	17
P1-12	543	539	541.0	TSPI	12

Table II presents the test in terms of the A-10 speed during firing and is based on time, space, position information (TSPI) and the reading of heads up display (HUD) camera film. The table shows the A-10 aircraft attacking at speeds during the firing passes varying between 578 ft/sec (342 knots) and 499 ft/sec (295 knots) and averaging overall 535 ft/sec (316 knots). The firing speeds largely in excess of 300 knots combined with the clean, unencumbered configuration of the aircraft resulted in exceptional maneuverability of the aircraft during the attacks on the tank company.

Table II. -- TEST RESULTS: AIRCRAFT ATTACK VELOCITIES

PASS	DIVE ANGLE (°) OPEN-FIRE	CEASE-FIRE	AVG	SOURCE	±2σ TOLERANCE (°)
P1-1	5.3	4.7	5.0	TSPI	0.5
P2-1	4.2	5.3	4.8	HUD PITCH	2.8
P1-2	4.4	4.5	4.5	HUD PITCH	2.8
P2-2	4.4	4.4	4.4	HUD PITCH	2.8
P1-3	6.9	5.7	6.3	TSPI	0.5
P2-3	5.8	5.8	5.8	HUD PITCH	2.8
P1-4	5.4	3.3	4.4	TSPI	0.5
P2-4	5.6	5.6	5.6	HUD PITCH	2.8
P1-5	5.4	3.3	4.4	TSPI	0.5
P2-5	10.9	10.7	10.8	HUD PITCH	2.8
P1-6	10.6	7.8	9.2	TSPI	0.5
P2-6	6.5	6.5	6.5	HUD PITCH	2.8
P1-7	5.8	3.6	4.7	TSPI	0.5
P2-7	5.6	4.6	5.1	HUD PITCH	2.8
P1-8	9.9	8.1	9.0	TSPI	0.5
P2-8	8.3	8.3	8.3	HUD PITCH	2.8
P1-9	10.1	7.4	8.8	TSPI	0.5
P2-9	7.4	7.3	7.4	HUD PITCH	2.8
P1-10	7.6	5.6	6.6	TSPI	0.5
P2-10	10.4	9.5	9.9	HUD PITCH	2.8
P1-11	10.0	6.7	8.4	TSPI	0.5
P2-11	6.5	6.5	6.5	HUD PITCH	2.8
P1-12	7.9	5.9	6.9	TSPI	0.5

Table III presents the test in terms of the A-10 dive angles during the firing passes. The clearly configured aircraft were able to attack at low dive angles ranging between 4.4 and 10.8 degrees. The low dive angles resulted in an overwhelming predominance of impacts against the side surfaces of the hulls and turrets of the target tanks and relatively low vertical obliquities. In the test of 15 June 78, the M-47 tanks proved vulnerable to perforation through the armored side surfaces partly because of the dive angles and resulting low vertical obliquities.

Table III. -- TEST RESULTS: AIRCRAFT ATTACK DIVE ANGLES

PASS	REFERENCE TARGET	SLANT RANGE (feet) OPEN FIRE	SOURCE	±2σ TOLERANCE (feet)
P1-1	16	2186	TSPI	10
P2-1	15	2264	HUD FILM	460
P1-2	14	2296	HUD FILM	460
P2-2	5	3329	HUD FILM	460
P1-3	6	2682	HUD FILM	460
P2-3	7	4055	HUD FILM	460
P1-4	4	2795	TSPI	10
P2-4	11	3178	HUD FILM	460
P1-5	2	2373	TSPI	10
P2-5	2	2870	HUD FILM	460
P1-6	6	1942	TSPI	10
P2-6	12	2619	HUD FILM	460
P1-7	12	2024	TSPI	10
P2-7	11	2099	HUD FILM	460
P1-8	5	2710	TSPI	10
P2-8	16	3448	HUD FILM	460
P1-9	2	2434	TSPI	10
P2-9	4	3087	HUD FILM	460
P1-10	2	2253	TSPI	10
P2-10	16	3683	HUD FILM	460
P1-11	2	2152	TSPI	10
P2-11	6	4523	HUD FILM	460
P1-12	4	2401	TSPI	10

Table IV shows open fire slant ranges for pass at a primary target. The attacking pilots opened fire at medium ranges for the A-10/GAU-8 system averaging 2795 feet. The actual open fire ranges clustered near the statistical average, and, as medium ranges of engagement they resulted in effective ratios of accuracy and lethality for the system.

Table IV. -- THE RESULTS: AIRCRAFT ATTACK SLANT RANGES

Pilot 2: All right.

***** (10:40:09 Pilot-1's tenth firing burst.)

Pilot 1: Up on the east. Getting smoky out here.

Pilot 1: Count 240, Bill. Good pass, Jim.

Pilot 2: 100, Bill.

Pilot 1: Got 240. Copy that, Bill.

Ground: Yeah, I got it. Thank you.

Pilot 1: (10:40:50) We are going to be unable to hit that western one the furthest to the north (3rd platoon, tank 7). There's just too much smoke obscuring it.

Ground: Okay.

Pilot 1: And I am in on that one tank I shot at last time (2nd platoon, tank 2). That beauty does not want to burn.

Ground: Roger.

***** (10:41:03 Pilot 1's eleventh firing burst.)

Pilot 2: Okay, I'm up on the last tank (1st platoon, tank 6) east of the real good smoker.

Ground: Roger.

Pilot 2: Well, I hit him.

Pilot 1: Okay, Bill, we will make one pass apiece, more. We have hit every one of the tanks.

Ground: Understand, you think you hit them all. And you are going to make one more pass.

Pilot 1: We have definitely hit them all. They're not all burning.

Ground: Okay.

Pilot 2: (10:41:43) Yeah, we're getting some fires from the easternmost (1st platoon) now.

Pilot 1: Yeah, there we go. That's what I just shot at. I will be in on the command vehicle (tank 4) this time, Billy.

Ground: Roger that.

Pilot 1: If I can find it in the middle of that smoke I'm in.

Figure 7 is extracted from an in-flight recording of the pilots' comments during the firing. The recording shows that the pilots were faced with realistic battlefield obscuration, specifically smoke from the fires and explosions within the tanks which they had catastrophically damaged.

Figure 7. -- TRANSCRIPT OF PILOTS' IN-FLIGHT VOICE RECORDING, BATTLEFIELD OBSCURATION COMMENTS

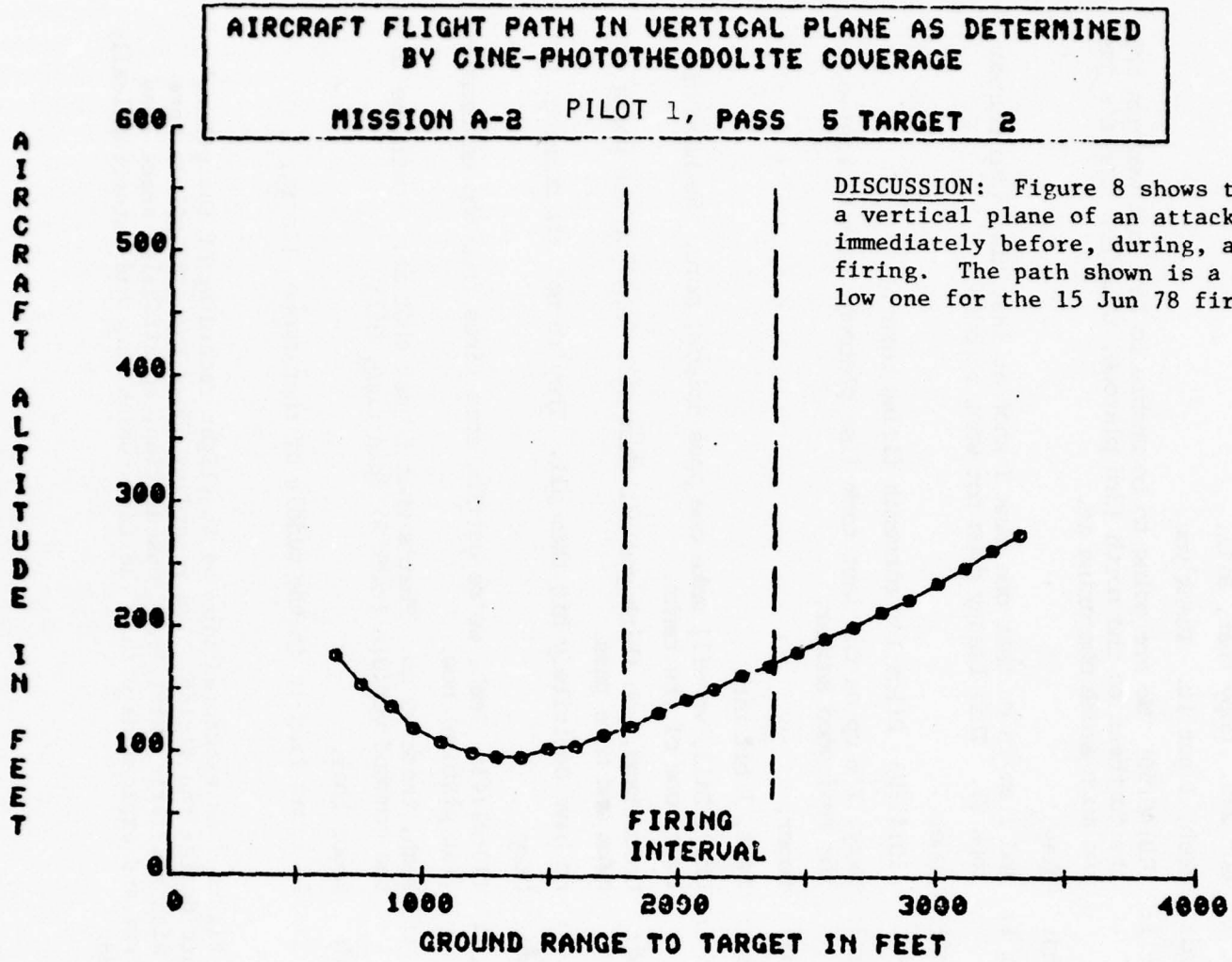
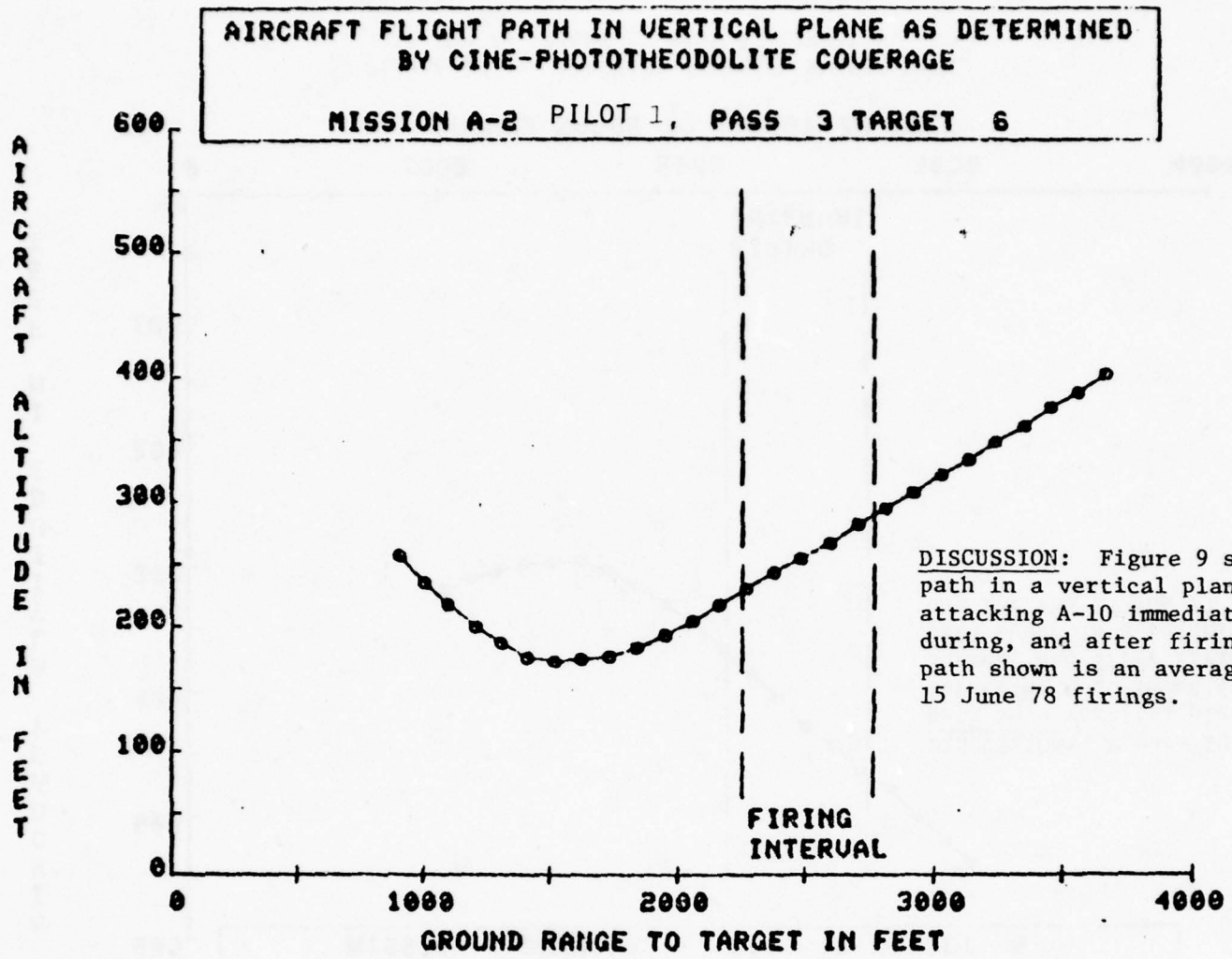
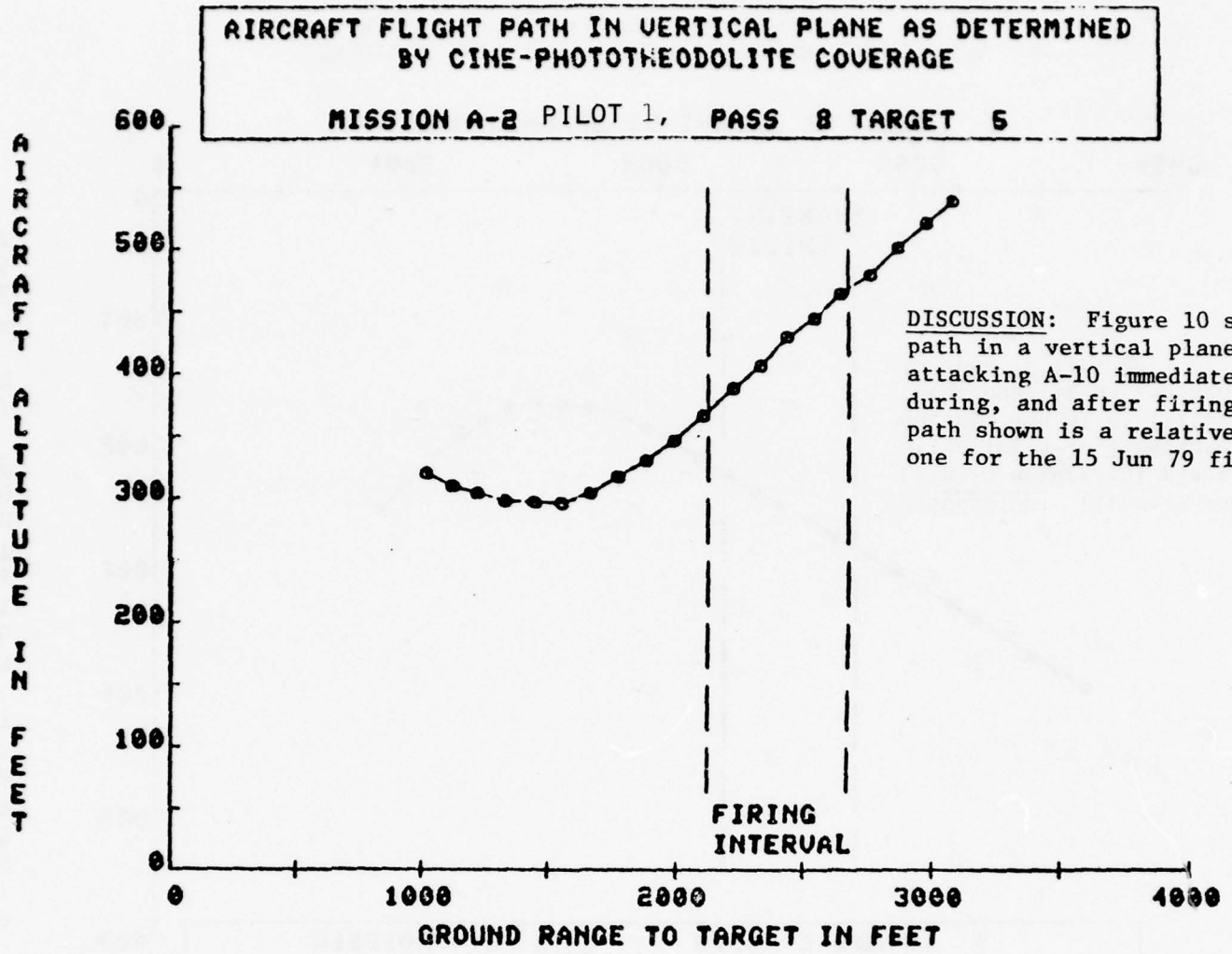


Figure 8. -- AIRCRAFT VERTICAL FLIGHT PATH, 15 JUN 79, PILOT 1, PASS 5, TARGET 2



DISCUSSION: Figure 9 shows the path in a vertical plane of an attacking A-10 immediately before, during, and after firing. The path shown is an average for the 15 June 78 firings.

Figure 9. -- AIRCRAFT VERTICAL FLIGHT PATH, 15 JUN 79, PILOT 1, PASS 3, TARGET 6



DISCUSSION: Figure 10 shows the path in a vertical plane of an attacking A-10 immediately before, during, and after firing. The path shown is a relatively high one for the 15 Jun 79 firings.

Figure 10. -- AIRCRAFT VERTICAL FLIGHT PATH, 15 JUN 79, PILOT 1, PASS 8, TARGET 5

PASS	BURST LENGTH (seconds) O	BURST LENGTH (seconds) S	ROUNDS FIRED O	ROUNDS FIRED S	SOURCE	±2σ TOLERANCE (rounds)
P1-1	1.07		70		TSPI[a]	0.5
P2-1		0.69		43	HUD[b]	2
P1-2	1.04		68		HUD	3
P2-2		1.00		64	HUD	2
P1-3	1.44		96		HUD	3
P2-3		1.75		117	HUD	2
P1-4	1.91		129		TSPI	0.5
P2-4		2.44		165	HUD	2
P1-5	1.14		75		TSPI	0.5
P2-5		1.54		103	HUD	2
P1-6	1.34		89		TSPI	0.5
P2-6		1.00		64	HUD	2
P1-7	0.81		52		TSPI	0.5
P2-7		1.46		96	HUD	2
P1-8	1.06		69		TSPI	0.5
P2-8		1.23		80	HUD	2
P1-9	1.26		83		TSPI	0.5
P2-9		1.44		95	HUD	2
P1-10	0.94		61		TSPI	0.5
P2-10		1.56		103	HUD	2
P1-11	0.90		58		TSPI	0.5
P2-11		1.73		115	HUD	2
P1-12	1.13		74		TSPI	0.5
AVERAGE	1.17	1.46	77	95		

NOTES: (a) Time, space, position information
(b) Head-up display

Table V shows the burst length and number of rounds fired during each pass. For aircraft P1, the average burst length was 1.17 seconds, which was realistically short from the viewpoint of non-maneuvering exposure to air defense fire. For the same aircraft, the average number of rounds fired was 77, which was a moderate amount, but one which promised effective numbers of impacts on targets and perforations through the armored envelope based on empirical ratios developed during testing in the LAVP. For aircraft P2, similar comments can be made.

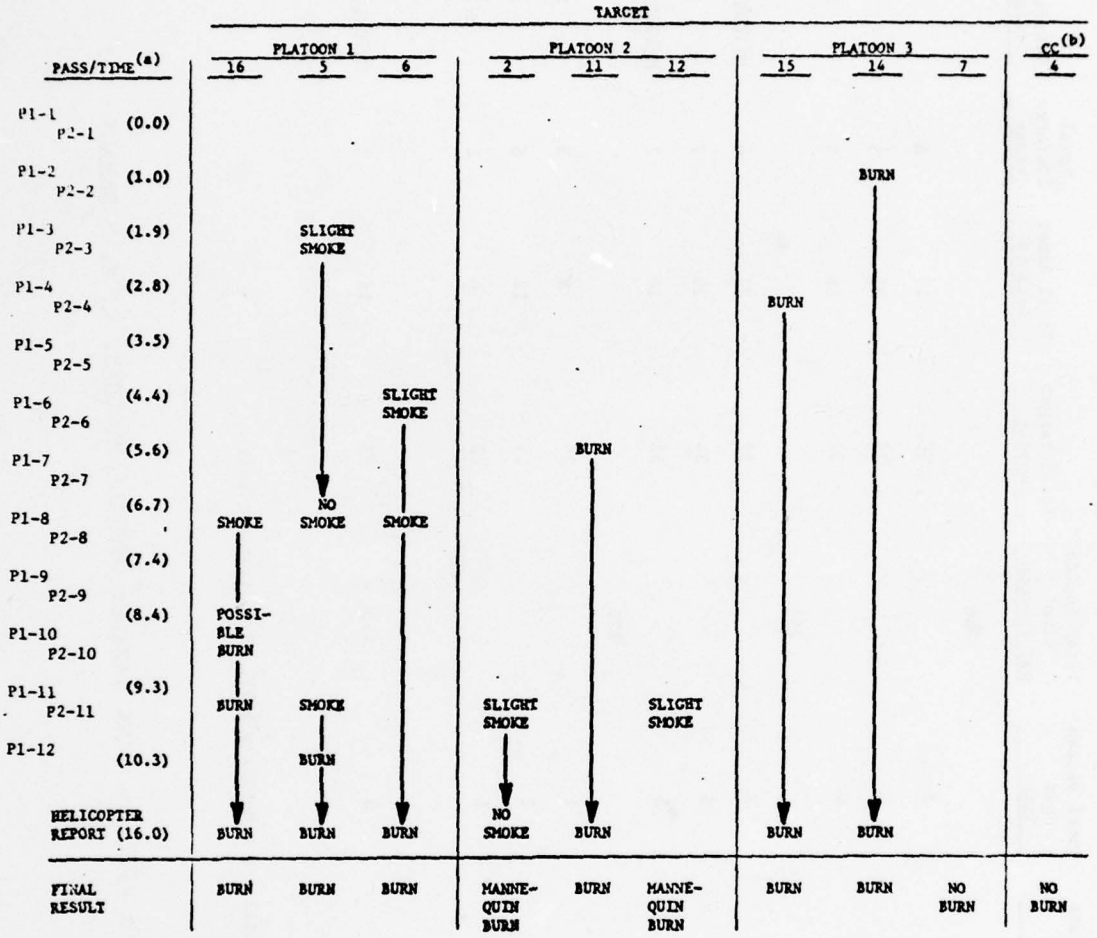
Table V. -- THE RESULTS: AIRCRAFT ATTACK, BURST LENGTHS AND ROUNDS FIRED

TOTAL ROUNDS FIRED = 1969

TARGET	ARRIVAL MODE			EFFECT ON ARMOR		
	GROUND RICOCHET	DIRECT HIT	TOTAL IMPACTS	ARMOR PERFOR-ATION	ARMOR PENE-TRATION	RICOCHET OFF ARMOR
Platoon 1						
16	6	24	30	8	9	0
5	9	67	76	9	21	2
6	2	30	32	3	11	2
Platoon 2						
2	7	52	59	4	20	3
11	3	31	34	7	12	1
12	3	29	32	7	8	1
Platoon 3						
15	1	24	25	3	5	0
14	0	14	14	6	3	3
7	1	11	12	1	3	0
Commander						
4	3	30	33	2	8	4
Mission Totals	35	312	347	50	100	16

Table VI shows the arrival mode of the projectiles which impacted the target tanks and the projectile effects in the cases where the projectiles impacted armor. The table shows that 90% of the projectiles directly impacted the target tanks while 10% arrived as ricochets off the ground. The direct impacts in turn were broken down into 53% which directly impacted the armor, and 47% which hit exterior components with varying but largely insignificant results against the armor.

Table VI. -- GUN EFFECTS: IMPACT CHARACTERISTICS VS TANKS



NOTES:

(a) Time in minutes after Pass 01
(b) Company Commander

Table VII shows the development of catastrophic damage in the tanks of the target array in terms of the observed progress of internal fires. Tanks 11, 14, and 15, for example, were observed to burn, i.e., suffer from major internal fires and/or explosions, within 5.6 minutes of the initial firing pass.

Table VII. -- TANK DAMAGE: BURN TIMES FOR K-KILLS

Target		Total Passes per Platoon	Total Passes per Tank	Total Rounds Fired per Platoon	Total Target Impacts	Total Armor Impacts	Total Perforations	Target Damage Assessment(a)
Platoon	Tank							
1		8		686				
	16		3		30	17	8	K
	5		5		76	32	9	K
	6		6		32	16	3	K
2		9		757				
	2		7		59	27	4	M(100%), F(95%)
	11		5		34	20	7	K
	12		5		32	16	7	M(100%), F(100%)
3		3		228				
	15		1		25	8	3	K
	14		2		14	12	6	K
	7		1		12	4	1	M(35%)
Company Commander								
	4		3	298	33	14	2	M(70%), F(100%)

NOTE:

(a) K = Catastrophic kill; M = Mobility kill; F = Firepower kill

Table VIII. -- TANK DAMAGE: OVERALL PICTURE; K, M, F DAMAGE

Target Platoon	Target No.	Target Damage Assessment[a]	Total Perforations	Turret Perforations	Engine Compartment Perforations	Hull Perforations
1						
	16	K	8	4	4	—
	5	K	9	4	4	1
	6	K	3	1	2	—
2						
	2	M(100%), F(95%)	4	3	—	1
	11	K	7	2	3	2
	12	M(100%), F(100%)	7	4	2	1
3						
	15	K	3	—	—	3
	14	K	6	4	—	2
	7	M(35%)	1	—	1	—
Company Commander						
	4	M(70%), F(100%)	2	2	—	—
			—	—	—	—
		TOTAL	50	24	16	10

NOTE:

(a) K = Catastrophic kill; M = Mobility kill; F = Firepower kill

Table IX. -- TANK DAMAGE, LOCATIONS OF PERFORATIONS

Accuracy Related Measures*

Ratios of Impacts to Rounds Fired:

$$\frac{\text{Impacts}}{\text{Rounds Fired}} = \frac{347}{1969} = 0.18$$ (includes impacts from ricochets off ground)

$$\frac{\text{Impacts}}{\text{Rounds Fired}} = \frac{312}{1969} = 0.18$$ (includes only direct impacts)

Lethality Related Measures

Ratios of Perforations to Impacts:

$$\frac{\text{Perforations}}{\text{Impacts}} = \frac{50}{347} = 0.14$$ (includes impacts from ricochets off ground)

$$\frac{\text{Perforations}}{\text{Impacts}} = \frac{50}{312} = 0.16$$ (includes only direct impacts)

*The impacts include ricochets off ground (as noted) and also impacts on secondary and incidental targets. Accuracy, then, is firing situation accuracy and not aircraft/gun accuracy per se.

Figure 11. A-10/GAU-8 MEASURES OF EFFECTIVENESS IN COMBAT SIMULATION OF 15 JUNE 78

A-10/GAU-8 Versus Simulated Soviet Tank Company
Ratios of Kills Per Pass
(Firings of 15 June 1978)

Primary Passes	Damage Results	Ratio of Kills Per Pass
23	8 Tanks Immobilized Consisting of 6 K-Killed and 2 M-Killed Vehicles	$\frac{8}{23} = 0.38$ Immobilizing Kills Per Pass
23	6 Tanks Catastrophically Killed	$\frac{6}{23} = 0.26$ Catastrophic Kills Per Pass

- - - - -

DISCUSSION:

Table X ties together aircraft attack parameters, weapon effects, and target damage, in effect, summarizing the entire firing test. The table shows that the pilots/planes/cannons had the skill/performance/effects to immobilize the MBTs in 38% of the firing passes and catastrophically destroy them in 26% of the passes.

Figure 12. A-10/GAU-8 VERSUS SIMULATED SOVIET TANK COMPANY RATIOS OF KILLS PER PASS

VI. Combat Damage Assessment

The CDAT functioned under the direction of a small Combat Damage Assessment Committee which was responsible for assessing the damage resulting from the attack, assigning kill factors, and publishing the overall report. The damage and kill assessment was based on cumulative damage from all attacks. Where possible, damage resulting from individual attacks was assessed independently as part of the overall evaluation of each target. Where the independent assessment of an individual attack is made, the assessment is presented with the caveat that when earlier attacks did not result in crew casualties or seriously degrade mobility the time between attacks provided for a significant change in posture of individual tanks on a dynamic battlefield with possible significant differences in results.

Some targets were assessed as catastrophically destroyed even though direct observation showed a delay between the attack and the burning or explosion of the vehicle. Such an assessment was made on the basis of evidence of simultaneous crew casualties which made it highly improbably that the crew would have any capability to resist the propagation of small fires into killing fires and explosions.

The assessment of weapon effects and the assignment of kill value is discussed below. Each target was examined

individually in an identical format which includes a description of the attack/passes; the number of impacts resulting in perforations, significant damage, and insignificant damage; and the rationale behind the overall assessment.

Tank Target Damage Summary
M-47 Tank Number 2

1. Description of A-10 Attack on Tank 2: Within a period of 6 minutes, tank 2 was primary target on 5 firing passes and secondary target on 2 passes.

2. Kill Assessment: M-100%, F-95%, K-O, resulting from the following impacts.

a. Perforations - 4

b. Significant Impacts - 16 (Contribute to M or F kills) Damage to exterior M and F components.

c. Insignificant Impacts - 38 (Do not contribute to M or F kill: effective maintenance procedures require repair or replacement of damaged components.)

3. Rationale for Kill Assessment:

a. M-100%: based on crew casualties from 4 perforations and cumulative damage to exterior mobility components especially the penetrated hub of right number 3 road wheel (Impact 42) and the driver's periscope (Impact 30) (See Figs. 15 and 16)

b. F-95%: based on crew casualties from 4 perforations and cumulative damage to exterior firepower components especially the tank commander's and gunner's periscope heads (Impacts 11, 29) (See Figs. 13 and 14).

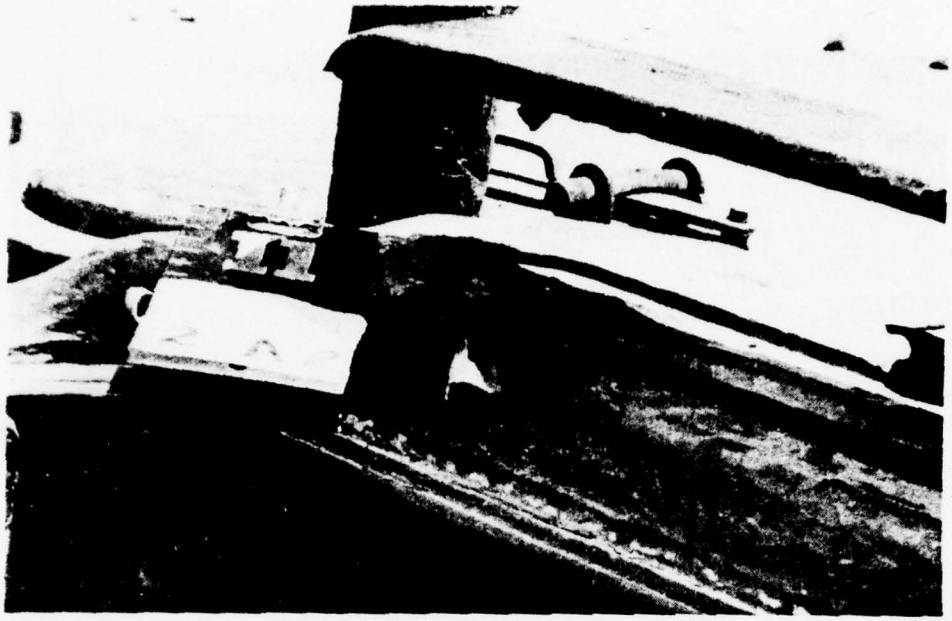


Figure 13. -- TARGET 2, IMPACT 11

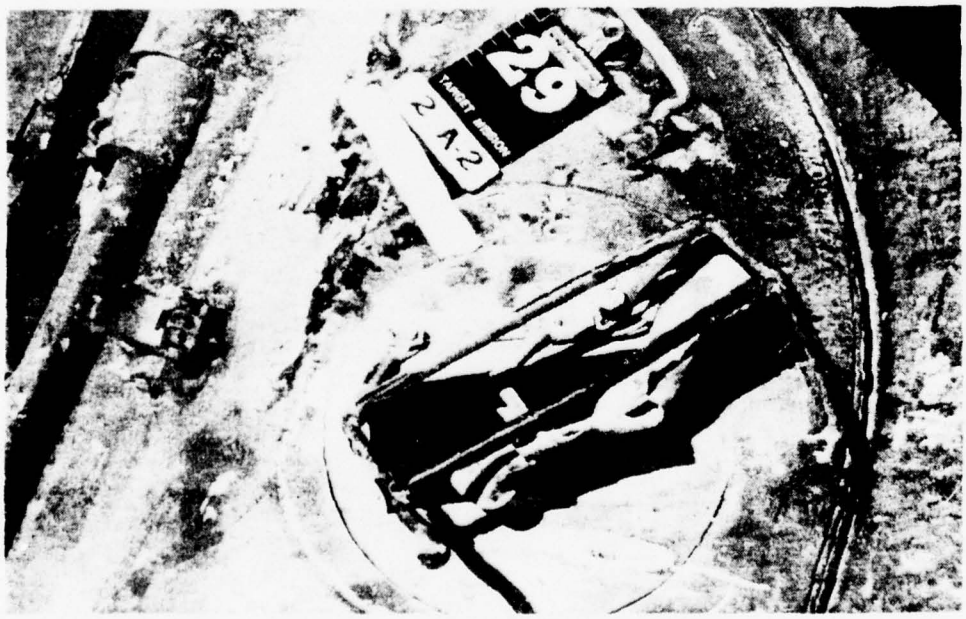


Figure 14. -- TARGET 2, IMPACT 29

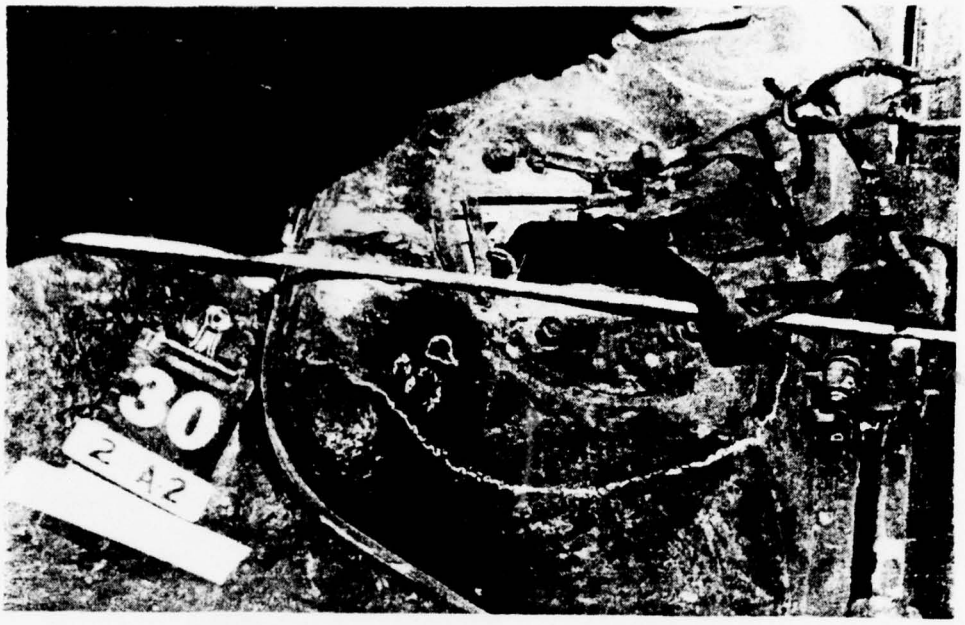


Figure 15. -- TARGET 2, IMPACT 30

Figure 16. -- TARGET 2, IMPACTS 41 AND 42

Tank Target Damage Summary
M-47 Tank Number 4

1. Description of A-10 Attack on Tank 2: Within a period of 7.6 minutes, tank 4 was primary target on 3 firing passes.

2. Kill Assessment: 70% M-Kill and 100% F-Kill resulting from the following observed effects.

a. Perforations - 2

b. Significant Impacts - 8, which contribute to assessment of M and F kills through resultant damage to exterior M and F components.

c. Insignificant Impacts - 23, which do not contribute to M and F kills. Effective maintenance procedures, however, require repair or replacement of damaged components.

3. Rationale for Kill Assessment:

a. M-70%: based on cumulative damage to exterior mobility components especially the penetrated right number 5 road wheel hub (Impact 18) and cracked number 1 track support wheel hub (Impact 28). (See Figs. 20 and 21).

b. F-70%: based on wounded L (Impact 5), damaged rangefinder (Impact 8), and perforated gun tube (Impact 12) (See Figs. 17, 18, and 19).

Figure 17. -- TARGET 4, IMPACT 5

Figure 18. -- TARGET 4, IMPACT 8

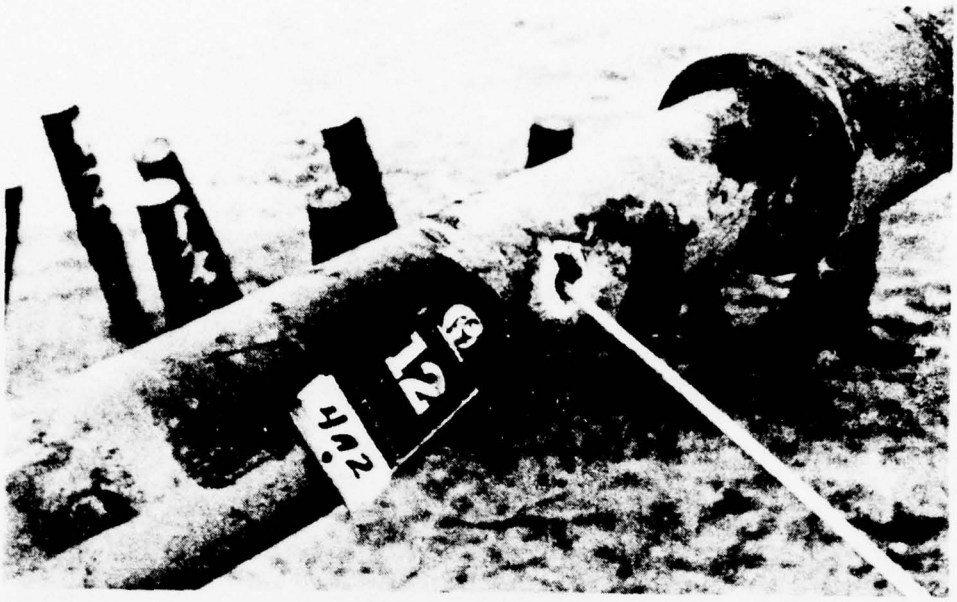


Figure 19. -- TARGET 4, IMPACT 12

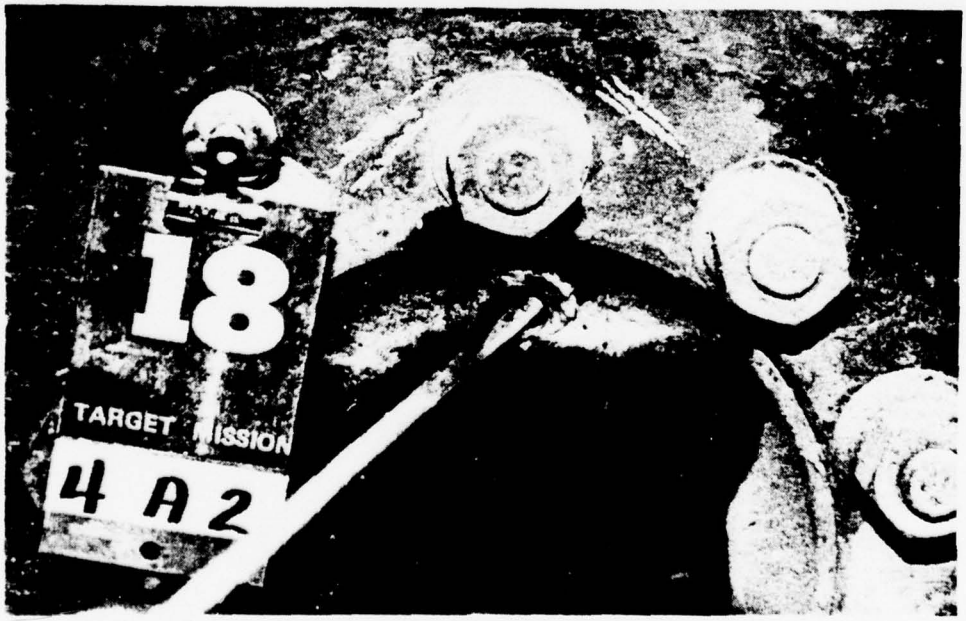


Figure 20. -- TARGET 4, IMPACT 18

Figure 21. -- TARGET 4, IMPACTS 28 AND 29

Tank Target Damage Summary

M-47 Tank Number 5

1. Description of A-10 Attack on Tank 5: Within a period of 8.6 minutes, tank 5 was impacted as primary target on 2 firing passes and secondary target on 3 passes.

2. Kill Assessment: K-Kill, resulting from the following impacts.

a. Perforations - 9

b. Significant and Insignificant Damage resulted from 67 additional impacts, but all such damage was overridden in importance by the catastrophic internal effects of the 9 perforations.

3. Rationale for Kill Assessment: Every one of the 4 perforations into the turret and 5 perforations into the hull could have ignited either fuel or ammunition. By 10.3 minutes from the time it was first fired on, tank 5 was observed burning. Several minutes earlier the tank was observed smoking and the CDAT concludes that a fuel (or oil) fire was ignited and rapidly developed into catastrophic explosions of stowed ammunition and ignition of fuel in main cells. The crew casualties assessed from perforations 5, 6, 8, and 11 would have prevented the crew from controlling any internal fire. (See Figures 22, 23, 24 and 25.)

Figure 22 . -- TARGET 5, INTERIOR VIEW OF IMPACTS 5 AND 6

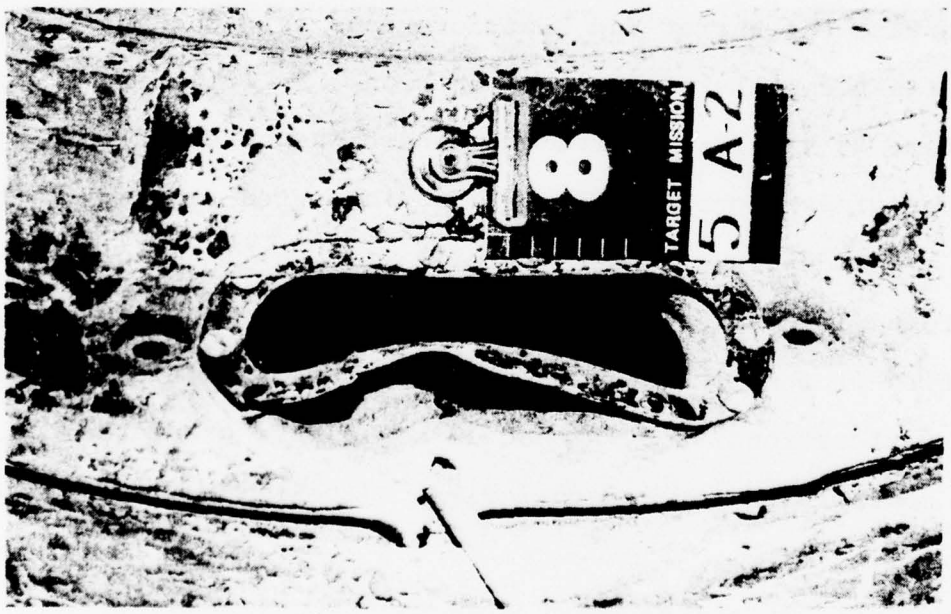


Figure 23 . -- TARGET 5, IMPACT 8

Figure 24 . -- TARGET 5, IMPACT 11

Figure 25. -- TARGET 5, INTERIOR VIEW OF IMPACT 11

Tank Target Damage Summary
M-47 Tank Number 6

1. Description of A-10 Attack on Tank 6: Within a period of 8.4 minutes, tank 6 was impacted as primary target on 3 firing passes, secondary target on 2 passes, and incidental target on 1.

2. Kill Assessment: K-Kill resulting from the following observed effects.

a. Perforations - 3

b. Significant and Insignificant Damage resulted from 29 additional impacts. All such damage, however, was overridden in importance by the catastrophic internal effects of the 3 perforations.

3. Rationale for Kill Assessment: Two perforations (10 and 33, see Figs. 27, 28) were achieved into the engine compartment and both were capable of igniting fuel or oil in that area. One additonal perforation (3, see Fig. 26) through the TC's cupola had the capability of killing or wounding the three crew members in the turret and igniting their clothing. The tank was observed to be smoking 3.2 minutes after it had been fired upon and the CDAT made the assessment that a fuel or oil fire was propagated by the combined effects of perforations 3, 10, and 33, which caused the fire and prevented the crew from controlling it.

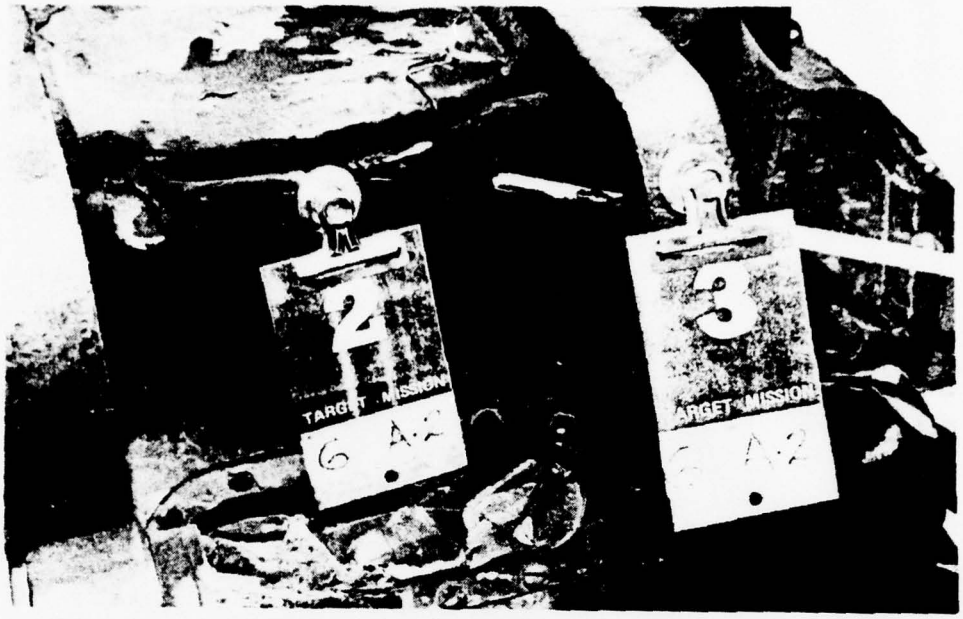


Figure 26 . -- TARGET 6, IMPACT 3

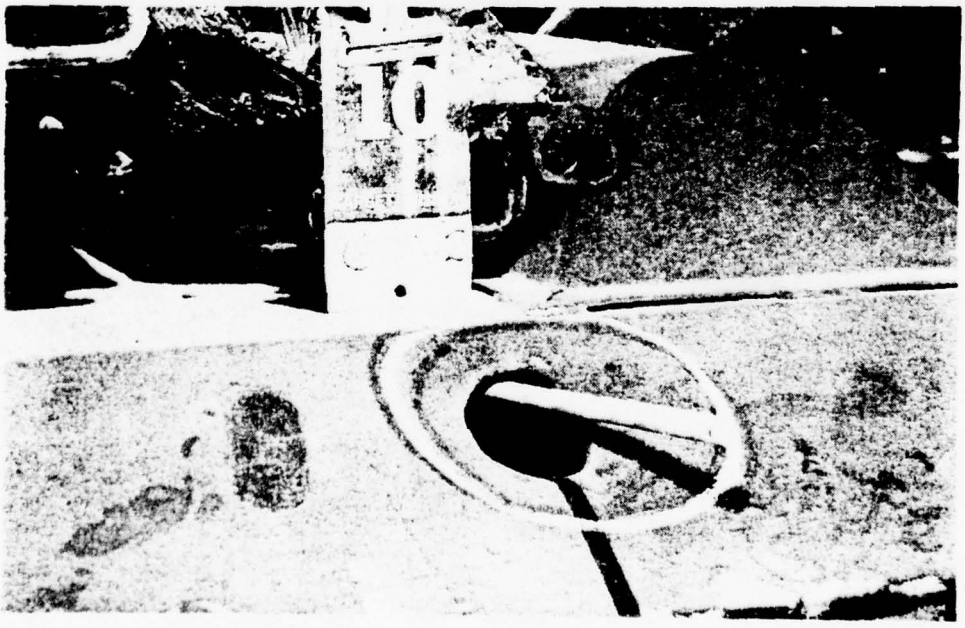


Figure 27 . -- TARGET 6, IMPACT 10

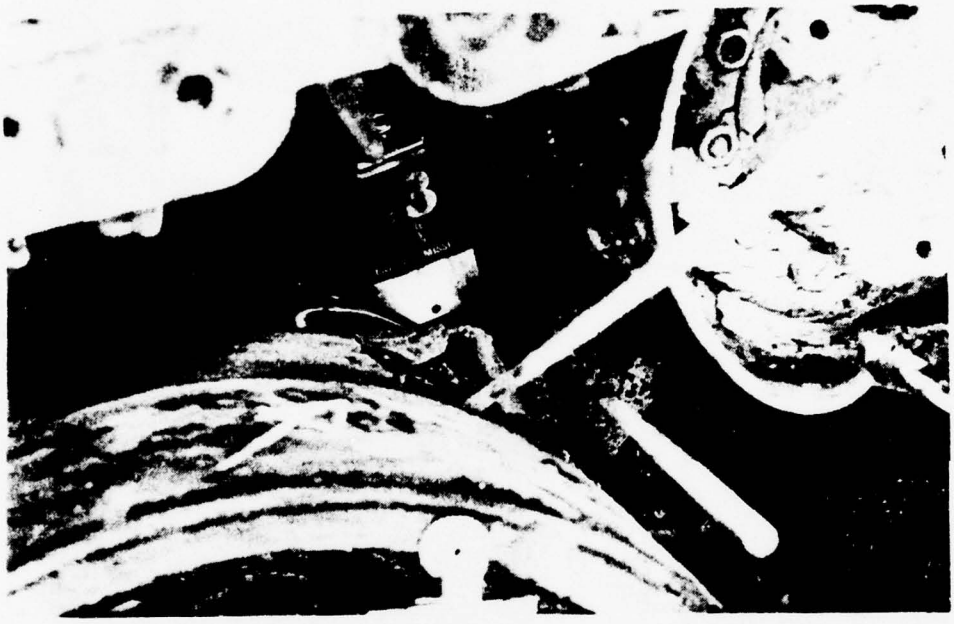


Figure 28. -- TARGET 6, IMPACT 33

Tank Target Damage Summary
M-47 Tank Number 7

1. Description of A-10 Attack on Tank 7: The target tank was impacted as primary target on 1 firing pass from the right side.

2. Kill Assessment: 35% M-Kill resulting from the following impacts.

a. Perforations - 1

b. Significant and Insignificant Damage resulting from 11 additional impacts.

3. Rationale for Kill Assessment: One perforation was achieved into the transmission compartment (impact 1, see Fig. 29). Although the transmission was not damaged, the impact damaged the right drive sprocket. Six additional hits (non-perforating impacts) were scored (impacts 3, 5, 6, 9, 10, and 11), which significantly damaged the track, road wheels, and track support rollers of the target tank. The partial mobility kill was assessed on the basis of the cumulative damage resulting from impact 1 and also especially impacts 9 and 10 (see Figs. 30 and 31).

Figure 29 . -- TARGET 7, IMPACT 1

Figure 30. -- TARGET 7, IMPACT 9

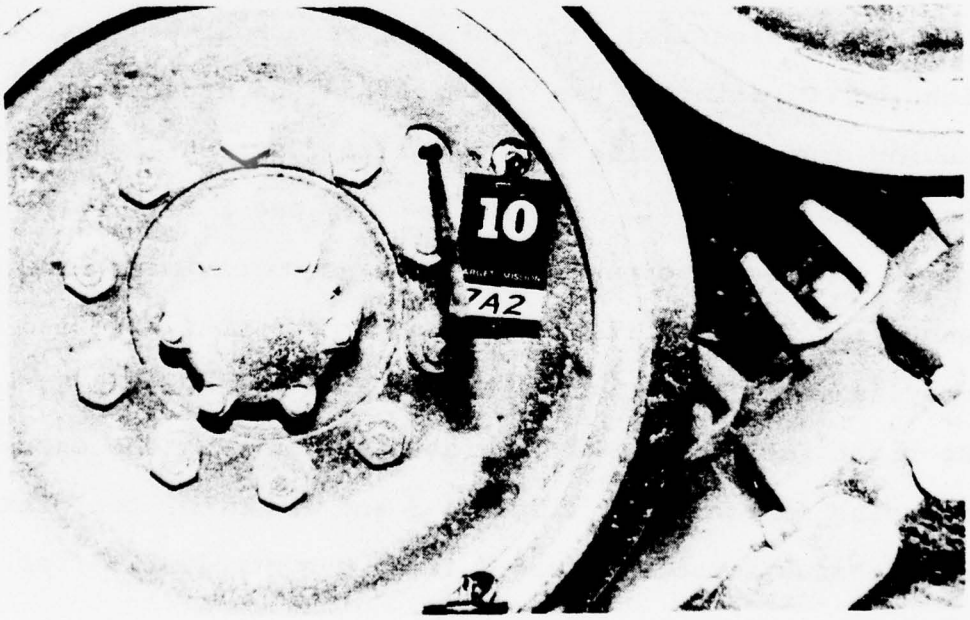


Figure 31. -- TARGET 7, IMPACT 10

Tank Target Damage Summary
M-47 Tank Number 11

1. Description of A-10 Attack on Tank 11: Within a period of 4.4. minutes, tank 11 was impacted as primary target on 2 firing passes, secondary target on 1 pass, and incidental target on 2 passes all from the right side.

2. Kill Assessment: K-Kill resulting from the following observed effects.

a. Perforations - 7

b. Significant and Insignificant Damage resulting from 27 additional impacts. All such damage, however, was overridden in importance by the catastrophic internal effects of the 7 perforations.

3. Rationale for Kill Assessment: Three perforations (3, 4, and 27; see Figs. 32, 33, and 38) were achieved into the fighting compartment, two of which had the capability of causing crew casualties and/or igniting stowed ammunition. Four perforations (12, 13, 18, and 23; see Figs. 34, 35, 36, and 37) were achieved into the engine compartment, one of which penetrated into the right fuel tank. The CDAT assessed an immediate K-Kill resulting largely from perforation 23 through the right fuel tank, which in combination with the casualty-producing perforations (impacts 3 and 4), other perforations, and external impacts resulted in an uncontrollable fuel fire.

Figure 32. -- TARGET 11, IMPACT 3

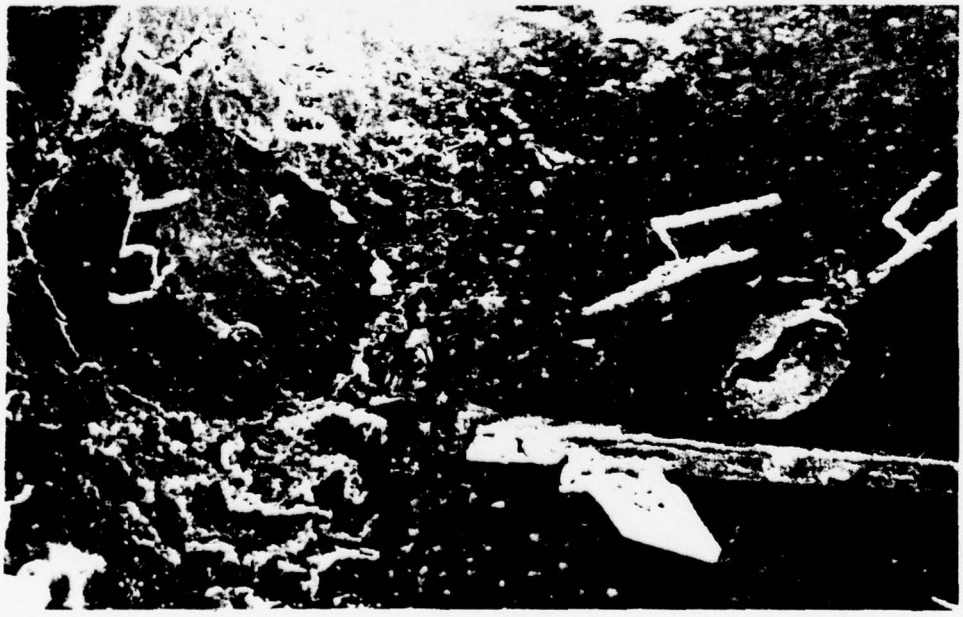


Figure 33. -- TARGET 11, INTERIOR VIEW OF IMPACT 4

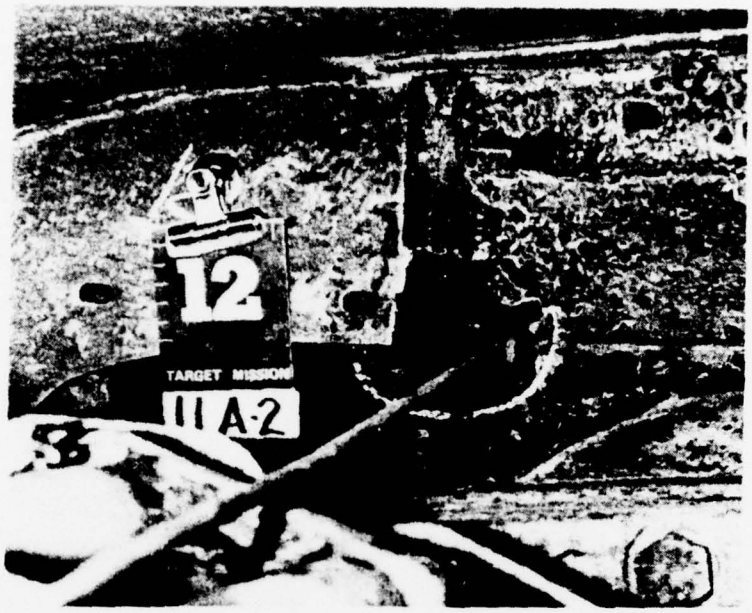


Figure 34 . -- TARGET 11, IMPACT 12

Figure 35 . -- TARGET 11, IMPACT 13

Figure 36. -- TARGET 11, IMPACT 18

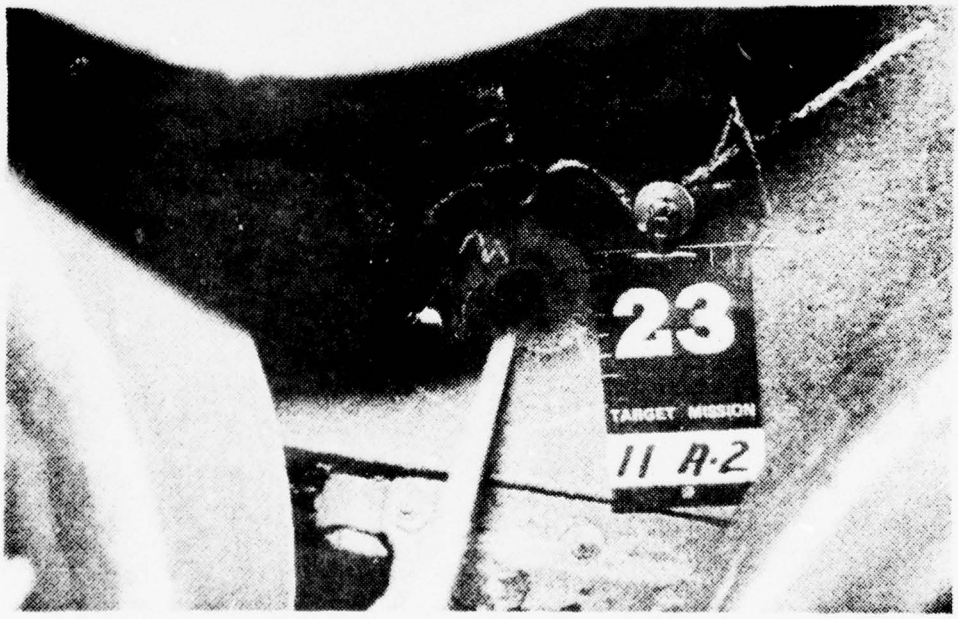


Figure 37. -- TARGET 11, IMPACT 23

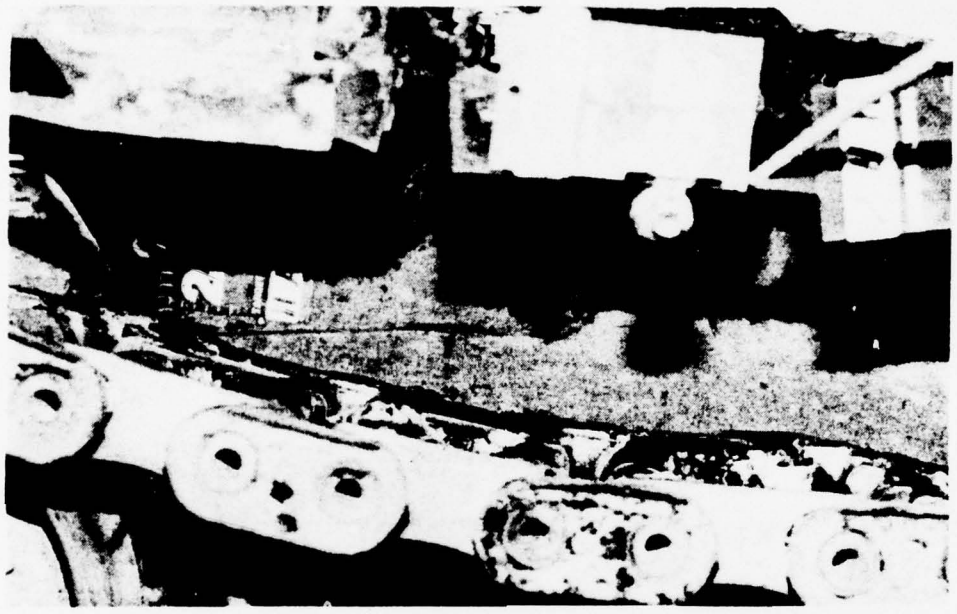


Figure 38. -- TARGET 11, IMPACT 27

Tank Target Damage Summary

M-47 Tank Number 12

1. Description of A-10 Attack on Tank 12: Within a period of 2.6 minutes, tank 12 was impacted as primary target on 2 passes, secondary target on 1 pass, and incidental target on 2 passes all from the right side.

2. Kill Assessment: 100% M-Kill and 100% F-Kill resulting from the following observed effects.

a. Perforations - 7

b. Significant Impacts - 10, which contribute to assessment of M and F kill through resultant damage to exterior M and F components.

c. Insignificant Impacts - 15, which do not contribute to M and F kill. Effective maintenance procedures, however, require repair or replacement of damaged component.

3. Rationale for Kill Assessment:

a. M-100% based on perforations 5, 6, 7 and 27, which killed or wounded all five crew members, perforation 15, which damaged engine and transmission, and eight additional impacts, especially numbers 17, 19, and 22, which significantly damaged exterior mobility components.

b. F-100%: based on perforations 5, 6, 7, and 27, which killed or wounded all five crew members, and impacts 20 and 23, which jammed the turret making it impossible to traverse.

c. See Figs. 39, 40 and 41 for photographs illustrating the weapon effects and damage from impacts 7 (gunner casualty), 17 (road wheel hub penetrated), and 20 (turret jammed).

Figure 39. -- TARGET 12, IMPACT 7

Figure 40. -- TARGET 12, IMPACT 17

Figure 41 . -- TARGET 12, IMPACT 20

Tank Target Damage Summary
M-47 Tank Number 14

1. Description of A-10 Attack on Tank 14: Within a period of 0.9 minutes, tank 14 was impacted as primary target on 1 firing pass and secondary target on 1 additional pass from the right front and right side respectively. The tank was observed to explode internally during the primary pass from the right front.

2. Kill Assessment: K-Kill resulting from the following observed effects.

a. Perforations - 6

b. Significant and Insignificant Damage resulting from 8 additional impacts. All such damage, however, was overridden in importance by the catastrophic effects of the 6 perforations.

3. Rationale for Kill Assessment: The CDAT assessed the damage to tank 14 as an immediate catastrophic kill based on the observed internal ammunition explosion during the first firing pass against it. Perforation number 13, which had the location, azimuth, and residual energy to contact and (ignite) stowed ammunition was the killing agent (see Figs. 42 , 43).

Figure 42. -- TARGET 14, IMPACT 13

Figure 43. -- TARGET 14, INTERIOR VIEW OF IMPACT 13

Tank Target Damage Summary
M-47 Tank Number 15

1. Description of A-10 Attack on Tank 15: This tank was impacted as primary target on 1 firing pass. During the pass, the attacking pilot fired 43 rounds in a 0.69-second burst with 25 impacts on target.

2. Kill Assessment: K-Kill resulting from the following observed effects.

a. Perforations - 3

b. Significant and Insignificant Damage resulting from 22 additional impacts. All such damage, however, was overridden in importance by the catastrophic effects of the 3 perforations.

3. Rationale for Kill Assessment: Two projectiles (impacts 2, and 3) perforated the hull armor and penetrated into the right fuel tank. One additional projectile (impact 11) perforated the hull armor at the right front of the fighting compartment with high probability of resultant fragment/spall wounds to one crew member (bow gunner). The tank was observed to be burning intensely approximately 2.5 minutes after the firing pass. The CDAT assessed a K-Kill resulting from the rapid propagation of a major fuel fire which could not be controlled by the unwounded crew members (see Fig. 44 for impacts 2, 3 into fuel tank).

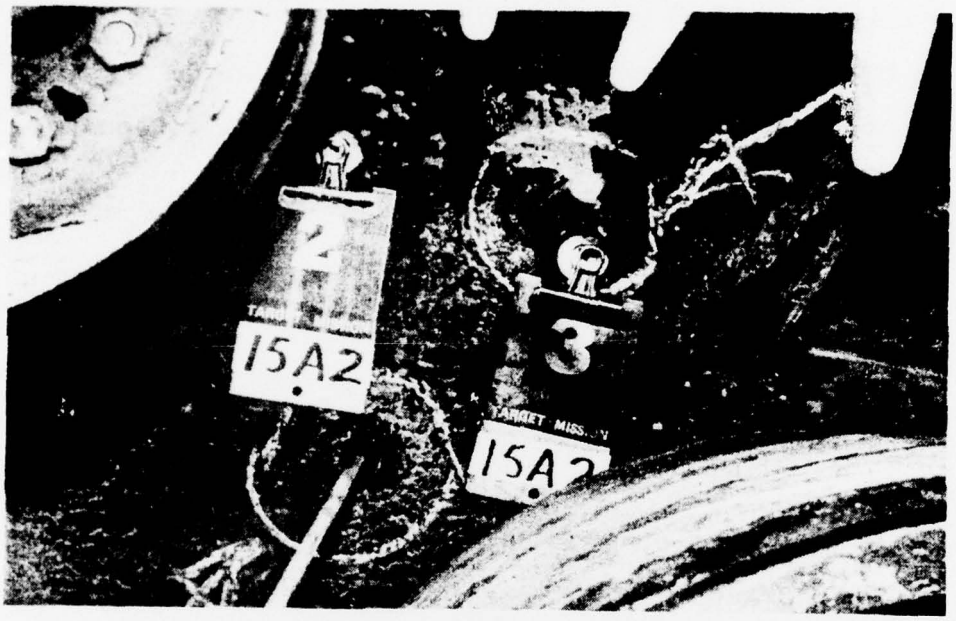


Figure 44 . -- TARGET 15, IMPACTS 2 AND 3

Tank Target Damage Summary
M-47 Tank Number 16

1. Description of A-10 Attack on Tank 16: Within a period 8.6 minutes, tank 16 was impacted as primary target on 3 firing passes all from the right side.

2. Kill Assessment: K-Kill resulting from the following observed effects.

a. Perforations - 8

b. Significant and Insignificant Damage resulting from 22 additional impacts. All such damage, however, was overridden in importance by the catastrophic effects of the 8 perforations.

3. Rationale for Kill Assessment: Four projectiles (impacts 8, 10, 12, 13) perforated the right side of the turret with high probability of causing casualties to tank commander, gunner, and loader. Four projectiles (impacts 5, 7, 18, 20) perforated the engine compartment armor with indeterminate damage but probable ignition of fuel and/or oil in that area. The target began to smoke immediately after the second firing pass against it, and 2.6 minutes later, shortly after the third firing pass, was observed to be burning. The CDAT assessed a K-Kill resulting from the rapid propagation of a fuel fire during and after the second firing pass, which could not be controlled by the crew (see Figs. 45, 46, 47, 48, 49, 50 for impacts 8, 12, 18 and 20, as representative perforations of turret and engine compartment).

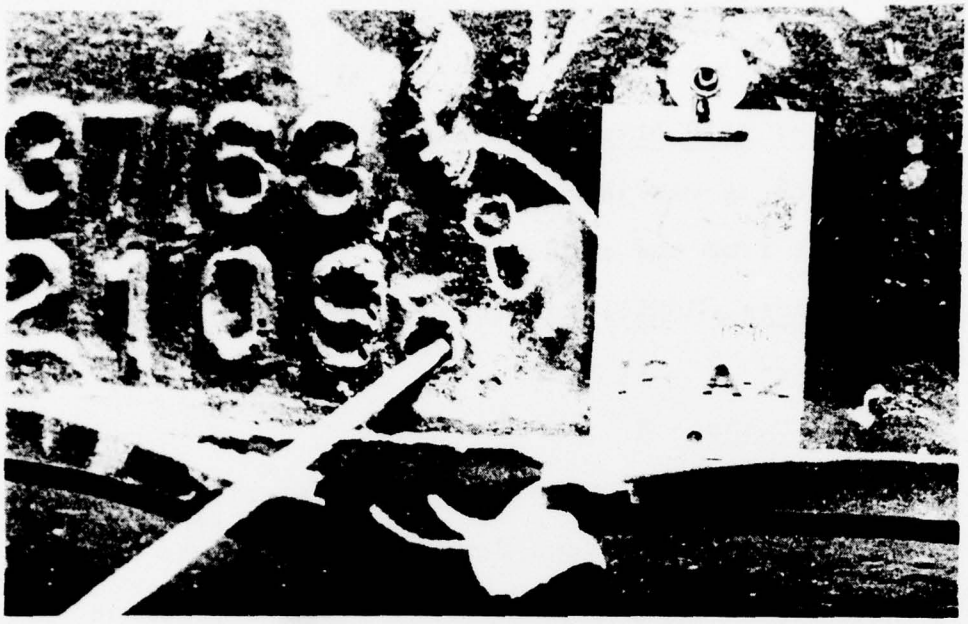


Figure 45. -- TARGET 16, IMPACT 8

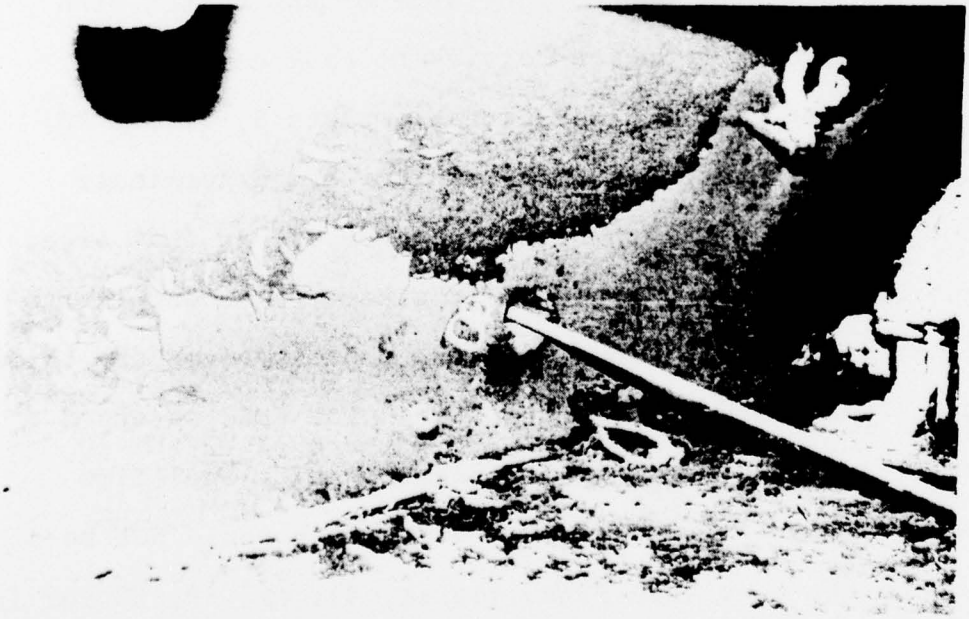


Figure 46. -- TARGET 16, INTERIOR VIEW OF IMPACT 8

Figure 47 . -- TARGET 16, IMPACT 12

Figure 48 . -- TARGET 16, INTERIOR VIEW OF IMPACT 12

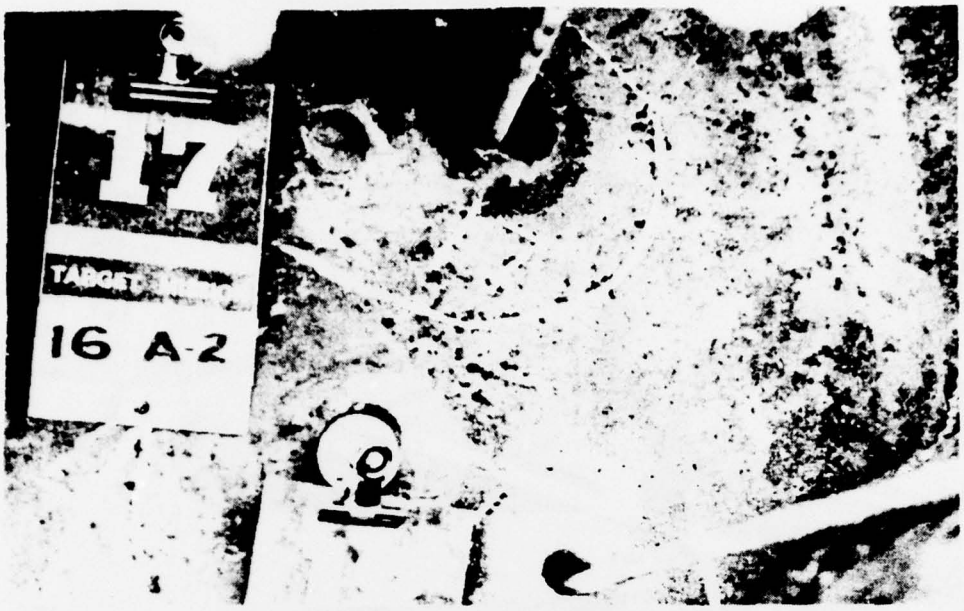


Figure 49 . -- TARGET 16, IMPACTS 17 AND 18

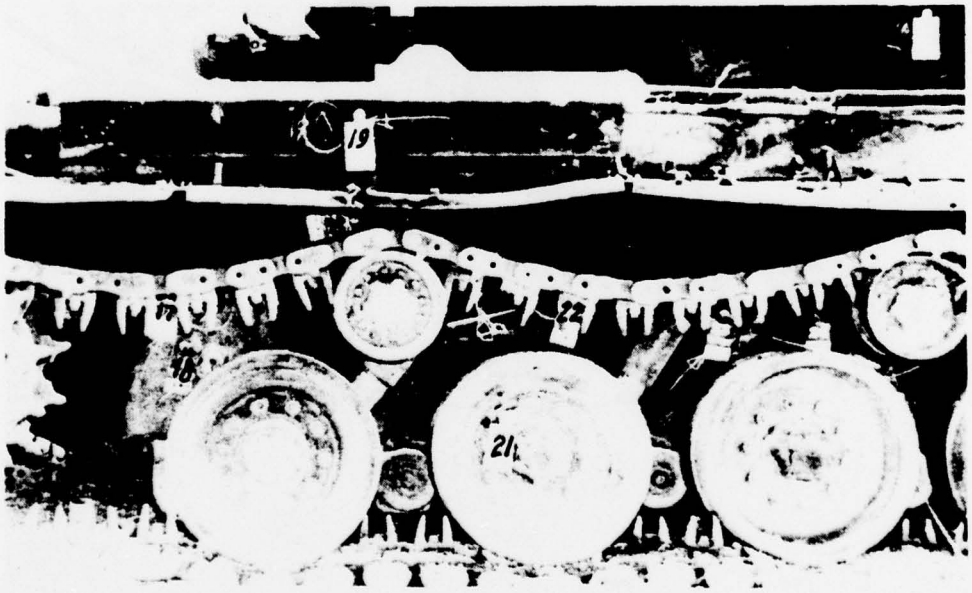


Figure 50 . -- TARGET 16, IMPACTS 17, 18, 19, 20, 21, 22, 23, AND 24

VII. Summary and Conclusions

On 15 June 1978, at Nellis AFB, Nevada, the Combat Damage Assessment Team (CDAT) conducted firings of the A-10/GAU-8 weapon system against an array of 10 tanks simulating a Soviet tank company deployed for an attack. The purpose of the firing test was to evaluate the effects of the 30mm API antitank ammunition of the GAU-8 gun under challenging conditions of engagement for the A-10/GAU-8 system against realistically simulated Soviet tank formations. The CDAT used M-47 tanks stowed with main gun ammunition, diesel fuel, lubricating oil, and crew mannikins to simulate the Soviet tanks. The pilots of the two A-10 aircraft used in the firings conducted their attacks at low altitudes and low dive angles which simulated attack below the altitude of effective engagement for opposing air defense systems using acquisition and fire control radar.

The firing test can be summarized in terms of the following data which were collected and/or extracted from the firings:

Aircraft Parameters

1. Speed (average) - - - - - - - - - - - 316 knots
2. Dive Angle (average)- - - - - - - - - 7.1°
3. Open Fire Slant Range (average) - - 2759 ft
4. Burst Length/Rounds (averages)- - - 1.3 sec/86 rds
5. Number Passes (primary) - - - - - - - 23
6. Target Aspects (predominantly)- - - Right Side

Weapon Effects		Target Damage	
1. Rounds Fired - - - - -	1969	1. K-Kills- - - -	6
2. Impacts- - - - - - - -	347	2. Hi% M+F Kills-	3
3. Ricochets (off grnd) -	35	3. M Kill - - - -	1
4. Direct Hit (non-perf)-	262	4. F Kill - - - -	0
5. Perforation- - - - - -	50	5. Negligible - -	0

These data and the more detailed base from which they were extracted can be arranged into measures of effectiveness for the A-10/GAU-8 system under conditions similar to those in the firing test, i.e., empirical combat simulation. The following values of effectiveness are based on the firing test on 15 June 1978 and can be expected to be similar in future empirical simulations of combat:

Measures of Effectiveness

Accuracy Related Ratio:

$$\frac{\text{Direct Impacts}}{\text{Rounds Fired}} = 0.16$$

Lethality Related Ratio:

$$\frac{\text{Perforations}}{\text{Direct Impacts}} = 0.16$$

Weapon System Effectiveness Ratio:

$$\frac{\text{Tank Immobilized}}{\text{Passes}} = 0.39$$

Weapon System Effectiveness Ratio:

$$\frac{\text{Tanks K-Killed}}{\text{Passes}} = 0.26$$

The ten target tanks were attacked predominately from the right side and suffered the severe damage shown in Figure 1 and Table VIII. Seven of the tanks, however, were impacted more than once as primary targets, and all of the tanks were also secondary and/or incidental targets during passes directed primarily against neighboring tanks. The large number of primary passes and accompanying secondary and incidental impacts help to explain the severe damage to the tank and contrasting moderate ratios of damage and kills per pass.

The data and measures summarized above, and the other data contained in this report, support several conclusions:

1. The A-10/GAU-8 system in realistic simulation of

combat is capable of inflicting K, M and F Kills on M-47 and similarly protected main battle tanks, e.g., Soviet T-55 and T-62 tanks.

2. The system in low level attacks can perforate specifically the side and rear surfaces of the hulls and turrets of M-47 and similarly protected main battle tanks.

3. The system is an effective killing agent against the side and rear surfaces of M-47 and similar tanks when firing moderate length bursts of 1.0-1.5 sec/65-100 rds.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, VA. 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, CA. 93940	2
3.	Department Chairman Department of National Security Affairs Naval Postgraduate School Monterey, CA. 93940	2
4.	Professor R.H.S. Stolfi Department of National Security Affairs Naval Postgraduate School Monterey, CA. 93940	15
5.	CAPT L. O. Ratley III, USAF ASD/YXA Wright Patterson AFB, OH 45433	20
6.	MAJ Charles Earnhart AFIT/CIP Wright-Patterson AFB, OH. 45433	2
7.	COL James C. Keenan AFIS/INH Ft. Belvoir, VA. 22060	1
8.	BRIG GEN William D. Curry 355 TFW/CC Davis Monthan AFB, AZ. 85707	1
9.	COL Wayne E. Davis 1411 Gemini Circle Moody AFB Valdosta, GA. 31601	1

10. COL Robert Dilger — 20
ASD/YXA
Wright-Patterson AFB, OH. 45433

11. COL W. S. Harpe — 1
AFMPC/DPMY
Randolph AFB, TX. 78148

12. BRIG GEN James R. Hildreth — 1
ACWAL/AIMVAL JTDD
Nellis AFB, NV. 89191

13. COL J. McFadden — 1
354 TFW/DCM
Myrtle Beach AFB, SC. 29577

14. Mr. C. E. Meyers — 1
Department of Defense
Office of Defense Research and Engineering
The Pentagon
Washington, D.C. 20301

15. BRIG GEN T. H. McMullen — 1
TAC/DR
Langley, AFB, VA. 23665

16. DEAN OF RESEARCH — 2
Naval Postgraduate School
Monterey, CA 93940

17. General Elwood Quesada (Retd.) — 1
L'Enfant Plaza
Washington, D. C. 20024

18. Mr. P. M. Sprey — 1
Box 264, R.D. 1
Glenn Dale, MD. 20769

19. Mr. Thomas Turner — 2
Fairchild Industries
Germantown, MD. 20767

20. Industrial College of the Armed Forces — 1
Library
Ft. Lesley J. McNair
Washington, D. C. 20319

21. Mr. Bernard Kornhauser — 1
System Planning Corp.
1500 Wilson Blvd.
Suite 1500
Arlington, VA. 22209

22. MAJ G. H. Felix, USAF — 1
Marine Corps Command & Staff College
Quantico, VA. 22134

23. USMC Development & Education Cmd — 3
Quantico, VA. 22134

24. USAF TAWC — 5
Eglin AFB, FL. 32542

25. HQ USMC — 5
Deputy Chief of Staff Requirements
MAJ GEN P. X. Kelley
Arlington, VA. 22212

26. USAF Air University Library — 1
Maxwell AFB, AL. 36112

27. CMDR, Naval Weapons Center — 2
China Lake, CA. 93555
ATTN: Mr. Bates

28. Commander — 5
(COL R. Gomez)
Ballistic Research Laboratory
Aberdeen Proving Ground, MD. 21005

29. GE, Armament Systems Dept. — 1
Director
Lakeside Ave.
Burlington, VT. 05401

30. HQ TAC/DO — 1
Langley AFB, VA. 23665

31. 354 TFW/DO — 2
Myrtle Beach AFB, SC. 29577

32. 23 TFW/DO — 2
England AFB, LA. 71301

33. USAC 4SC — 1
Ft. Leavenworth, Kansas 66027

34. 355 TFW/DOW — 1
Davis Monthan AFB, AZ. 85707

35. 355 TFW/DO(A-7) — 1
Davis Monthan AFB, AZ. 85707

36. 355 TFW/DO(A-10) — 3
Davis Monthan AFB, AZ. 85707

37. 333 TFTS/CC — 1
Davis Monthan AFB, AZ. 85707

38. 333 TFTS/DO — 1
Davis Monthan AFB, AZ. 85707

39. 333 TFTS/WPNS (CAPT Haar) — 2
Davis Monthan AFB, AZ. 85707

40. AFTEC A-10 Test Force/CC — 1
Davis Monthan AFB, AZ. 85707

41. OLAC 4444 OPS SQ (ISD) — 1
Davis Monthan AFB, AZ. 85707

42. 355 TTS/CC — 1
Davis Monthan AFB, AZ. 85707

43. Mr. Bob Forker — 1
Hughes Helicopters
Ordnance Division
Culver City, CA. 90230

44. Herrn Dr. Granier — 1
Bundesarchiv-Militärarchiv
78 Freiburg im Breisgau
Wiesentr 10
West Germany

45. Herrn Dr. Horst Boog — 2
Wiss Oberrat
Militärgeschichtliches Forschungsamt
7800 Freiburg im Breisgau
West Germany

46. LT COL Robert G. Appelbaugh — 1
USAF TAWC/TEFE
Eglin AFB, FL. 32542

47. Albert F. Simpson — 2
Historical Research Center
Maxwell AFB, AL. 36112

48. CMDR Naval Air Systems Command — 1
ATTN: PMA 235 B
Washington, D. C. 20361

49. CMDR McMichael — 1
DASD/ISA/ED
Rm 4D800
The Pentagon
Washington, D. C. 20301

50. LT COL Howard J. Pierson — 1
180 Magnolia
Shaw AFB, SC. 29152

51. USAF — 2
DCS/Plans & Operations
Directorate of Operations
Tactical Division
BF939B
The Pentagon
Washington, D. C. 20301

52. USAF — 2
DCS/Programs & Resources
Director of Programs
Tactical Branch
4C152
The Pentagon
Washington, D. C. 20301

53. USAF — 2
DCS/Research & Development
Directorate of Operational Requirements
& Development Plans
Tactical Division
5E381
The Pentagon
Washington, D. C. 20301

54. HQ TAC/DO AT — 1
Langley AFB, VA. 23665

55. HQ TAC/DO O — 2
Langley AFB, VA. 23665

56. HQ TAC/DOOO — 2
Langley AFB, VA. 23665

57. HQ TAC/DOOF — 1
Langley AFB, VA. 23665

58. HQ TAC/XP — 1
Langley AFB, VA. 23665

59. USAF Academy — 2
Library
USAF Academy, Colo. 80840

60. USAF TFWC/TA — 1
Nellis AFB, NV. 89191

61. 57 FWW/DO — 1
Nellis AFB, NV. 89191

62. 12 AF/DO — 2
Bergstrom AFB, TX. 78743

63. 9 AF/DO — 2
Shaw AFB, SC. 29152

64. CINCUSAFE/DO — 1
Ramstein AFB
APO 09012

65. CINCUSAFE/DOOF — 2
Ramstein AFB
APO 09012

66. CINCUSAFE/DOOT — 2
Ramstein AFB
APO 09012

67. CINCUSAFE/DOST — 2
Ramstein AFB
APO 09012